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ABSTRACT

This book is designed to provide elementary science methods teachers with a vehicle that will allow them to help their own students become scientifically literate. Chapters include: (1) "On Understanding Science and Technology"; (2) "Why Teach Science to Children"; (3) "The Process Side of Science"; (4) "The Product Side of Science"; (5) ""Models of Instruction"; (6) "Evaluation-Evaluating Students and the Effectiveness of Instruction"; (7) "Models for Action-Hands On Science Programs"; (8) "Science Textbooks-Analyzing and Modifying Them for Use in the Classroom"; (9) "Beyond the Textbook"; and (10) "Understanding and Teaching Environmental Education." Appendices include: a short history of elementary science methods; writing and analyzing instructional objectives; supplementary reading assignment; metric measurement; textbook appraisal; and safety in the classroom. (JRH)

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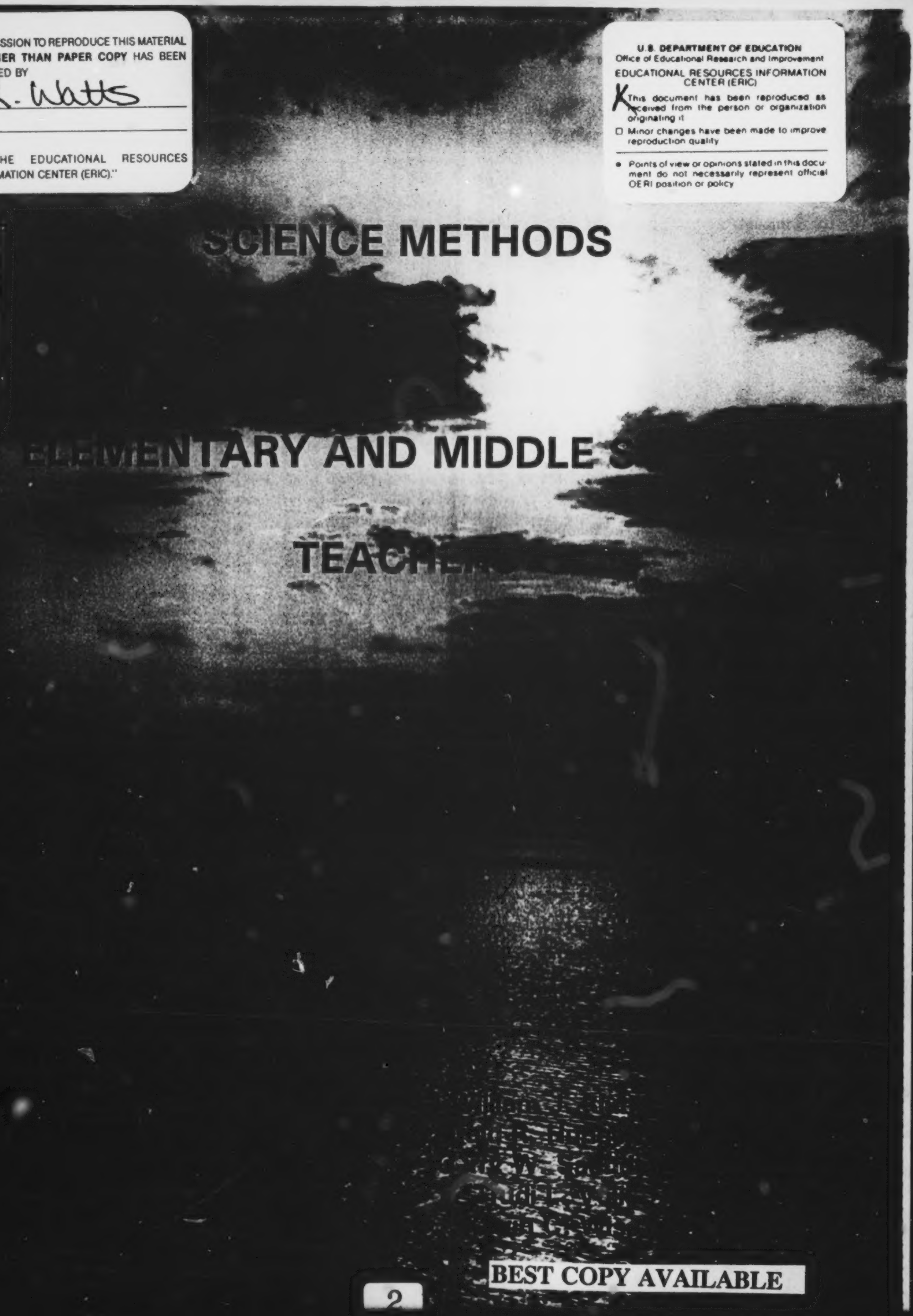

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SCIENCE METHODS
FOR
ELEMENTARY AND MIDDLE SCHOOL
TEACHERS

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The contributions of a great number of people over a period of many years have helped tremendously in the development of this book. The reactions of our elementary science methods students to the materials contained herein have greatly facilitated our effort to design a well-rounded book.

Perhaps none contributed more to this work in the early stages than the late Audrey Tomera whose dynamic teaching helped shape what appears here.

As past editions were developed, many professional educators willingly offered their knowledge and expertise concerning the content of this methods book. We owe these individuals our sincere expression of thanks. Among these persons are:

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The reality of the present text is in large part due to the unending patience, energy, and skill of Ms. Lois Cornett who typed revision upon revision until the authors finally got it right!

Over the years a number of artists contributed their talents to the development of this methods book. The visual appeal of this particular edition has been enhanced because of the pen and ink drawings of Ms. Rachel Goodlett.

Needless to say, the ultimate goal of this publishing effort is to provide, for our many methods students, a vehicle which will allow them to help their own students become scientifically literate.

The Authors, May 5, 1995

TABLE OF CONTENTS

Acknowledgements....i
Table of Contents....iii

Chapter I - On Understanding Science and Technology....1

What Is Science....2
And What of Technology....8
A Closing Thought and a Question....14

Chapter II - Why Teach Science To children?....15

Teaching Science With a General Education Perspective....16
Scientific Literacy - The Major Consideration....16
Other Considerations of Scientific Literacy....26
Conditions Necessary for an Effective Elementary Science Program....33

Chapter III - The Process Side of Science....35

An Observation Process Model....39
A Comparison Process Model....44
A Classification Model....48
Inferring Process Model....57
Hypothesizing Process Model....70
Interpreting Data....80
An "All Purpose" Process Model....90
Graphing Lesson Plan....102

Chapter IV - The Product Side of Science....107

The Product Side of Science....109
Fact in Science....109
Theories....111
Concepts....112
What Does This Mean for the Science Teacher?....117

Chapter V - Models of Instruction....121

Preparing Instructional Materials....122
The General Teaching Model....122
The Learning Cycle....131
The 5E Instructional Model....134

Chapter VI - Evaluation: Evaluating Students and the Effectiveness of Instruction...139

Evaluation Defined....140
Two Major Concerns in Evaluation: Validity and Reliability....141

An Introduction to Both Traditional and Nontraditional Forms of Assessment........143
Evaluating Knowledge: A Variety of Strategies........144
Evaluating Attitudes and Related Topics........156
Using Portfolios for Assessment........161
What Does the Teacher Need to Know........162

Chapter VII - Models for Action - Hands On Science Programs........163

Introduction........165
Science Curriculum Improvement Study........166
Full Option Science System........170

Chapter VIII - Science Textbooks: Analyzing and Modifying Them for Use in the Classroom........177

Strategies for Using the Textbook for Literacy........178
Analyzing the Science Textbook Series........181
Textbook Appraisal........182

Chapter IX - Beyond the Textbook........193

Community Resources........194
Field Trips........199
Incidental Science Experience........203
Supplemental Materials........207

Chapter X - Understanding and Teaching Environmental Education........213

An Example of Environmental Education in the School........214
What Is Environmental Education........218
So What? Why Should We Bother With EE?........218
Environmental Literacy Components........222
Where Does EE Fit?........225
Achieving Literacy! What is Involved???........227
The Role of Values Analysis........235
Educating for Citizenship Action........244
Sample EE Strategies........247

APPENDICES

Appendix A: A Short History of Elementary Science Methods........255

Appendix B: Writing and Analyzing Instructional Objectives........265

Appendix C: Supplementary Reading Assignment........273

Appendix D: Metric Measurement........275

Appendix E: Textbook Appraisal........277

Appendix F: Safety in the Classroom........289

Chapter One

On Understanding Science and Technology

> *Science in itself furnishes none of the ends of action; in so far as the knowledge of the scientist is concerned, it is immaterial whether what we know of high explosives is used to build a great reservoir to make the desert blossom as the rose, or to construct giant shells to snuff out the lives of an entire city. As a man the scientist may, nay, must, make some preference; but the grounds for that preference are not to be found in physics.*
>
> *Columbia Associates in Philosophy—1923*

Upon completion of Chapter One, you will be expected to be able to …

1. … name four different ways in which human beings gain truth or knowledge and discuss how these ways differ.
2. … define or identify accurate definitions of science and empiricism.
3. … diagram and/or explain the relationship that exists between "process" and "product" in science and explain why this relationship should be considered a cyclical one.
4. … provide at least one valid, actual example of the process < - > product relationship.
5. … define or identify an accurate definition of technology.
6. … diagram and/or explain the relationships that exist between science and technology.
7. … provide several examples of how scientific information has resulted in technological development.
8. … name the four different types of technology, describe each, and provide valid examples of each.
9. … identify/communicate at least one misconception that humans have concerning science and technology.
10. … discuss how technology changes society (the way people live) and present several valid examples from modern life.
11. … explain why it is important for young learners to have sound concepts of: (1) science and technology, (2) how science and technology differ, and (3) some of the potentials and limitations of science and technology.

On Understanding Science and Technology

Over the centuries, philosophers and common folk alike have struggled in an attempt to discover the role of humans in the universe. We humans tend to look at ourselves as unbearably complex and mostly uninterpreted. Unlike the other creatures to whom we are related, we are blessed—or burdened perhaps—with a highly developed, curious mind. The complexity of this organ does not permit us to escape the ties to the environment which we share with other creatures, but it does permit us what many would call the rationality and responsibility of being human. This, of course, refers to our ability to look at our environment, interpret it, and solve those solvable problems with which we choose to cope.

This rational quality separates us from the rest of the living creatures on the earth. It allows us to develop the thing called culture and all of the blessings and problems that culture brings with it. One of the products of the human mind, and an integral part of our culture, is science!

The writers who have dealt with the question, "What is science?" are many. If there are numerous responses to this question, then why do we deal with it here? The answer is simple. Teachers who propose to guide students toward accurate concepts concerning science and scientists must have clear and thorough concepts themselves before they can adequately broach the topic in the classroom. Indeed, the lack of accurate concepts of science and scientists may well provide a partial answer to help explain a lack of understanding concerning what science education should encompass. It seems to the writers that prime prerequisites for competent science instruction (and learning) are workable and accurate concepts of science and the scientist.

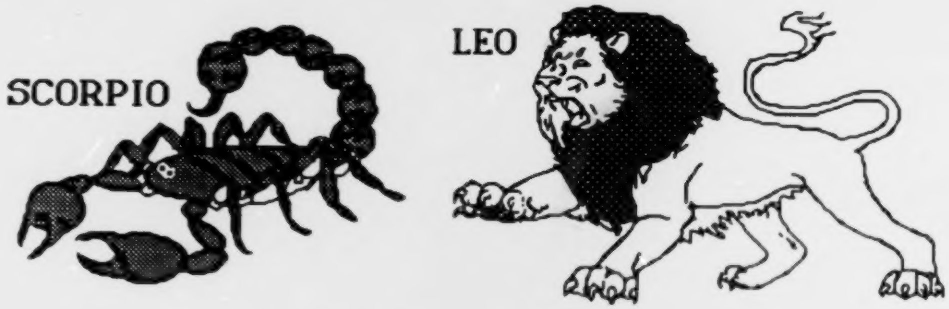
What Is Science?

Pseudo Science

A pseudo science is a practice that is based on little or no evidence. It is sometimes called "false science." Pseudo sciences exist today! An excellent example is astrology. Large numbers of people believe in astrology and consult astrologers or horoscopes published in newspapers in order to plan activities or to know when to make important decisions. Late in President Reagan's term in office, there was considerable publicity given to the role of an astrologer in Mrs. Reagan's life. And, what of water witching? Palmistry? Phrenology? UFO's? Lucky numbers? Some advocates of these beliefs, practices and superstitions would state flatly that there is evidence that these things work or are true.

But, scientists can find no scientific evidence that these things are true. Scientific findings must be replicable, that is, repeatable—there must be a body of evidence that these things exist. Further, there must be agreement or consensus in the scientific community that the evidence exists.

If someone goes into the woods and sees a vision, that vision cannot be repeated under scientific conditions. Thus, that vision is outside the realm of science. When a palmist reads someone's palm and makes an accurate prediction, can that prediction be due to chance or to a lucky guess? Could it be an inference made from something the palmist learned from the client? In none of these circumstances, is there scientific evidence that the palmist is involved in anything other than a pseudo science!



Scorpio and Leo are two of the astrological symbols associated with astrology. Astrology was the ancient study of the movement of the sun, moon and stars. The early astrologers believed that there was a connection between the movement of heavenly bodies, and events which occurred on earth. According to the beliefs of astrology, the objects which were in the skies at the time of your birth determine your characteristics and abilities. Thus, if you were born while Leo "ruled" the skies, you would likely be forceful and would be a natural leader. Even to this day, many people still rely on astrologers to help them in making important decisions.

Ways of "Knowing"

Science is easy to define but rather hard to understand. Why is science hard to understand? It may be because science is really a philosophy about truth and knowledge—or a way of "knowing." But, science is not the only "way of knowing" we have available to us! Let's explore some of the ways that human beings get their "truth" or "knowledge."

Authority as a Way of Knowing: Many human beings look to "authority" as the source of truth! This philosophy means that, if an authority says something, it must be true. Most people rely on authority at one time or another. Some look to things in print as "authority," regardless of how accurate the publication may be. To others, an important person may be an authority figure. If that person says something, it is "truth"! It must not be argued with because an important person said it! This is an easy way to get knowledge or truth because you put your trust in someone else to find out what truth is.

Religion as a Way of Knowing: Another way that human beings get knowledge or "truth" is through religion—still another philosophy. Religious truths are abundant. There are the "truths" held by Christians, "truths" held by Jews, "truths" held by Moslems, "truths" held by Buddhists, etc. Each of the religions has its own "truth" or knowledge. This "truth" or knowledge is usually written down in a document like the Bible or the Koran. Different religions, or denominations within religions, may interpret these writings differently, but each interpretation is "truth" to the person of that religion or denomination. Thus, we have many different "truths" in religion. People of different religions may argue about which "truth" is true (correct). Many have even died when these arguments resulted in war. What are these kinds of "truth" called? The best term is probably "dogma" or dogmatic truth. Dogmatic truth is absolute! It is based on faith! In a way, it is similar to "authority."

Tenacity as a Way of Knowing: The "tenacity" method of getting truth is very interesting. Tenacity refers to "truths" which have been told over and over—so many times that they are taken for granted. And people hold on to these kinds of truth with great conviction. For example, if your family has believed in astrology for generations, chances are you believe this too. This "truth" has been passed down, over the years, by great grandparents, grandparents, and parents. How would you behave under these circumstances? You would believe that you do not have control over your own destiny. You would believe that your destiny is controlled by the movement and alignment of heavenly bodies. You would behave accordingly!

> The essential difference [between science and other methods of getting knowledge], of course, is that ideas in science are subject to experimental test, whereas those in other fields are not. It does not pay to lie [in science], because you will be found out.
> J. Maynard Smith, 1988

In society as a whole, tenacity operates as "conventional wisdom." There are things that the bulk of society believes, and these bits of knowledge are held tenaciously. Conventional wisdom has it that girls are not as good at math and science as boys. Conventional wisdom has it that government always has the welfare of the citizens as its goal. Conventional wisdom has it that technology can solve all of our environmental problems. Conventional wisdom has it that you can predict winter weather by observing woolly bear caterpillars. Right or wrong, many people believe some of these things and hold to their beliefs tenaciously.

An interesting thing about "tenacity" is that people tend to lock on to these beliefs even when there are mountains of evidence to the contrary. People have believed these things for such a long time that their beliefs constitute "truth" regardless of what others tell them or what the facts are.

Science as a Way of Knowing: The philosophy of science revolves around observation. In fact, science is sometimes called "sensory reality." This means that what we believe to be knowledge in science must be somehow observed—or—carefully inferred from what is observed. Thus, "knowing" or the "truth" of science must be "proved"—not in an absolute sense like some other truths but in an empirical sense. There must be evidence to back up the "truth." Empiricism (true science) is based on observation or experimentation to establish what is real or true. Thus scientists (also called empiricists) acknowledge scientific truth if it is observable or inferred from experimentation. If a scientist can make an observation or conduct an experiment and have the results verified by other scientists, the knowledge is considered to be "scientific" (i.e., valid)!

A simple example might help. An entomologist (a scientist who studies insects) travels to the rain forests of Brazil. There she collects several beetles which are identical to each other—ones that are not familiar to her. She goes to the books and scientific papers on beetles and realizes that no one has ever reported this particular insect before. She names the beetle, prepares a scientific paper describing this beetle, and publishes the article in a scientific journal. Has she produced scientific "truth"? The answer is "yes," if there is some way by which other scientists can observe her evidence. Thus, it is scientific truth if the scientist has preserved the specimens so that other scientists can observe that her findings are correct. Or it is scientific if others can go to the same location and observe the same insect. Either way, this is considered scientific "truth" because it is observable and others can confirm it.

Interestingly, science is simply a search for "truth" and it is not concerned with how human beings act on scientific information which is obtained. Science, as such, is concerned with establishing "truth" in the strictest sense—not in how that truth is used. Many people do not understand that the scientist, acting as a scientist, is searching for "truth" or knowledge. As a scientist, the person makes no judgment about how that knowledge is used. Some people argue that the scientist must be responsible for how the knowledge is used. What these people do not understand is that science is only the search for truth/evidence/knowledge. The scientist is the vehicle for gaining that truth/evidence/knowledge. This is the only thing that separates the scientist from other human beings. Now, the scientist, as an informed citizen, may well have some say in the way that the scientific information is used. And the scientist's word may carry a lot of weight in the decision. But society—not the scientist—makes the decision.

There are numerous cases in history where scientists' views were ignored by people who had the power to make decisions about how the information was to be used. When scientists first succeeded in producing a controlled nuclear reaction, they realized the tremendous implications of their work. Some of them argued, as members of society, that nuclear power should not be used for making weapons. Still, two A-bombs were dropped on Japan at the close of World War II. This demonstrates that scientists, at times, have very little control over their findings. Another example lies in the life of Alfred Nobel, the inventor of dynamite. Nobel, as a scientist, was able to find a way to make high explosives "safe." As a citizen he dreamed of people using dynamite for the betterment of mankind. Because things didn't turn out the way he dreamed they would, he established the Nobel Prizes and provided the money for them.

It is interesting that science, as such, is not concerned with the "rights," "wrongs," or "moral implications" of things. To some people, this means that science is not really a philosophy at all because philosophy tends to deal with these things. But science, as a philosophy, is simply a perspective about "truth"—empirical truth. It is one way of "knowing"—a very important way, because it deals so closely with the human experience and demands verification. And science holds great promise for mankind. But remember, the "promise" of science is not in the realm of science. The "promise" lies strictly in the ways human beings decide to use the information science produces.

Definitions of Science

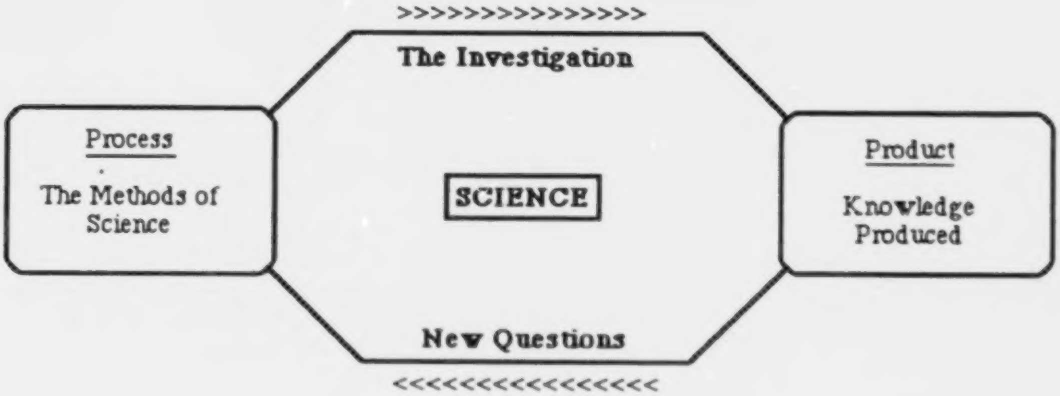
To the right are several definitions of science. Examine each one carefully. You might note that all of these definitions involve two very important elements: a process (the investigation) and a product (the knowledge). Although it is not reflected in these definitions, another important fact about scientific investigations is that they often produce more questions than answers. This is particularly true in experimental research.

Definitions of Science

- **Science is the process in which verifiable information is gained through empirical methods.**
- **Science is information provided by the processes involved in logically arranged investigations.**
- **Science is a combination of critical thought processes which result in a valid information product.**

It is safe to say that science involves both process and product. In other words, science includes both the seeking of new information or knowledge and the knowledge itself. And remember, this enterprise is guided by empiricism, the belief that the validity of the new knowledge can be both challenged and tested by the direct observations of others. We should be able to diagram this process < - > product relationship that is science.

The Process < - > Product Model of Science



You will learn more about the process side of science in Chapter Three. Chapter Four deals with the product side of science. For now, it is important that you gain an understanding of how science is an ongoing enterprise. Often it is our native curiosity which initiates science. Often, questions about how or why lead us to observe, to measure, to hypothesize and test our hypotheses. These activities (and several others) are considered science processes. The application of these scientific processes can lead us to answers, or explanations about how or why. In science, this knowledge (the product or result of our questioning) is made public to other scientists so that they may try to repeat it, and by doing that, test it in an empirical fashion. And, as was mentioned earlier, often these answers (scientific product) lead us or others to further questions, and to further observations, measurements, hypotheses, and tests. Because of this, we speak of science as a cyclical or ongoing enterprising.

Some more examples of the Process < - > Product Model of science might be helpful. Let us suppose that, as part of your science class, you wanted to do research into how animals react to light. You decide that you will set up a controlled experiment using mealworms (darkling beetle larvae) as the animal subjects. In your experiments you devise ways to test mealworms' reactions to various lighting conditions. This is the process side of your work. The results you get—the data you collect (the information you gather)—is the product side of your work.

Now, let's go back to the Process < - > Product Model once again. Here you see that research usually leads to more questions. How might this operate in your mealworm experiment? In your experiment, you used artificial light. As you gather your data you might begin to wonder if worms would react to natural sunlight in the same ways. Or you might wonder if other animals would react to different lighting conditions as the mealworms did. You might also wonder about the reactions of other animals like earth-worms or guppies or water fleas or brine shrimp. Here is where the model loops back to the process side with more questions. This is an interesting example of how research can lead to more questions than it answers. Of course, in the professional world of the scientist, the Process < - > Product Model is often more complicated than this mealworm example.

In the vignette about Louis Pasteur below, try and determine how his work fits into the Process < - > Product Model which you have just studied. You might want to research more thoroughly the work of Pasteur, because what you will read here is only a very brief summary of his many, many scientific accomplishments.

Louis Pasteur (1822-1895)

Louis Pasteur is considered by many to be one of the truly great scientific geniuses of all time. Many scientists, in the time of Pasteur, believed in the theory of "Spontaneous Generation." This is, they believed that living things could arise without parentage—that life was continually being created from non-life. Pasteur neither believed nor disbelieved the theory. Instead, he set about to conduct a series of experiments to determine whether the theory was correct. His experiments disproved the theory and helped change biology forever.

Pasteur is also famous for his discoveries which led to pasteurization. Most people associate pasteurization with milk. However, Pasteur developed this process in order to protect the French wine industry from disasters associated with the spoiling of wine. It was later applied to milk and other foods.

Pasteur was also responsible for bringing the science of immunology into existence. Interestingly, his first successes with immunizations were with farm animals—chickens, sheep, and cows. The next victory over disease was the one that many people associate his name with—rabies. In the 19th Century, many died from the bites from rabid animals. Rabies was thought to be a fatal disease without hope of being conquered.

But Pasteur, through his research with diseased rabbit tissue, gained enough knowledge to develop a vaccine that could protect dogs from the disease. In 1885, a young boy by the name of Joseph Maister, was brought to Pasteur. Maister had been bitten several times by a rabid dog. After consulting with the boy's doctor, Pasteur decided to inoculate the boy with his vaccine. The boy lived. Soon, others were saved from horrible deaths from rabies.

The bulk of Pasteur's work gave rise to a new theory in biology, The Germ Theory of Disease. Few theories have changed the course of science as much as this one. Many readers of this vignette owe their lives to Pasteur and the medical (technological) applications of this theory.

Be careful in your analysis of how Pasteur's work fits into the Process < - > Product Model. For example, you might want to focus on his research into rabies. You might say that his research on the rabies virus (the process part) resulted in a vaccine (the product part) that allowed people to be immunized against the disease. However, if you analyzed Pasteur's work this way you would be partly wrong!!! Why? First of all, you would be correct about the process. Pasteur's experimentation with the virus was, indeed, an example of the process side of science. However, the vaccine was not the product! The knowledge he gained about the virus was the product side. The development of the vaccine was, in reality, a technological application of the science information. Do you understand why this distinction might be made? Here we have basic science process (virus research) leading to new product (information about viruses) leading to the development of a vaccine (medical technology). However, even if you do not thoroughly understand these distinctions, do not worry because we will tell you more about them later on in this chapter.

And What of Technology?

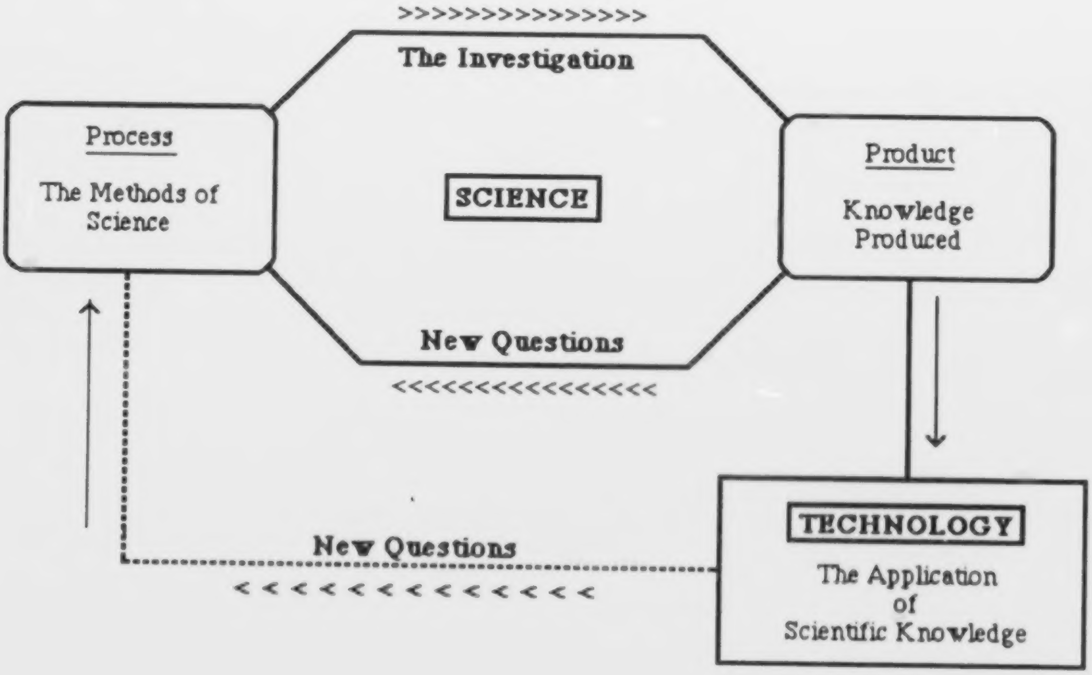
An Introduction

When you were asked to analyze the Pasteur vignette, you were introduced to the idea that "technology" is often closely associated with science. Indeed, the relationships are very close ones. But what of technology itself. What is it? What kinds are there? What are more of the interrelationships between science and technology?

Technology is often called "applied science." In other words, scientific information is somehow used to meet human wants and needs. Most of us know about technology and many of us confuse it with science. However, the distinctions are real and quite important in society. Sometimes technology is more than applied science. Oftentimes technology drives scientific research. Suppose we need some sort of "machine" or "system" or "product" to make life easier or to try to solve some problem facing society. At times like this, the technologist may turn to science and request basic research which might lead to that new "machine," "system," or "product."

Let's take a look at the Process < - > Product Model once again. Only this time, we will incorporate technology into that model. Let's see what it looks like. Study the Science - Technology Model below. Can you think of several examples that might fit this model? First, think about how some sort of science "product" or knowledge has been applied by humans to meet certain "wants" or "needs."

The Science - Technology Relationship


>>>>>>>>>>>>>>>
The Investigation
Process
The Methods of Science
SCIENCE
Product
Knowledge Produced
New Questions
<<<<<<<<<<<<<<<<<
TECHNOLOGY
The Application of Scientific Knowledge
New Questions
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One example of the science - technology relationship can be seen in eyeglasses. Scientists learned long ago that glass lenses would bend light rays in certain ways. This knowledge has been applied in the production of eyeglasses to correct faulty vision. Another example lies in the basic research done into the laws of heredity (genetics). Some of this knowledge has been applied in order to selectively breed row crops and livestock in agriculture. It has also been applied to produce new varieties of fruit, flowers, and vegetables.

And, of course, technology has had dramatic impacts on society and on how we live. Just think for a moment about technological products such as refrigerators, television sets, microwave ovens, hot water heaters, telephones, washers and dryers, freezers, electric lights, VCR's, home computers, flush toilets, bathtubs and showers. Take a few minutes to consider how life would be different if all of these things were instantly removed.

Sometimes we read slogans like: "Better Living Through Technology." A slogan like this one refers to things like the application of machines to reduce human labor, having appliances in the home to make living "easier," and increasing work output per man-hour with the application of technology.

It is easy to read this kind of slogan and slip on by it without giving it too much thought. But, perhaps it is important to critically inspect this slogan. Could the slogan, "Better Living Through Technology" be debated? If you were to argue with this statement, how would you do so? Does technology increase the complexity of society? Does it bring with it problems? If so, what kind of problems? Can we solve technologically-created problems with more and better technology? Many people think we can!

Just what do you think? Take some time and mull this whole topic over. What are your conclusions?

Types of Technology

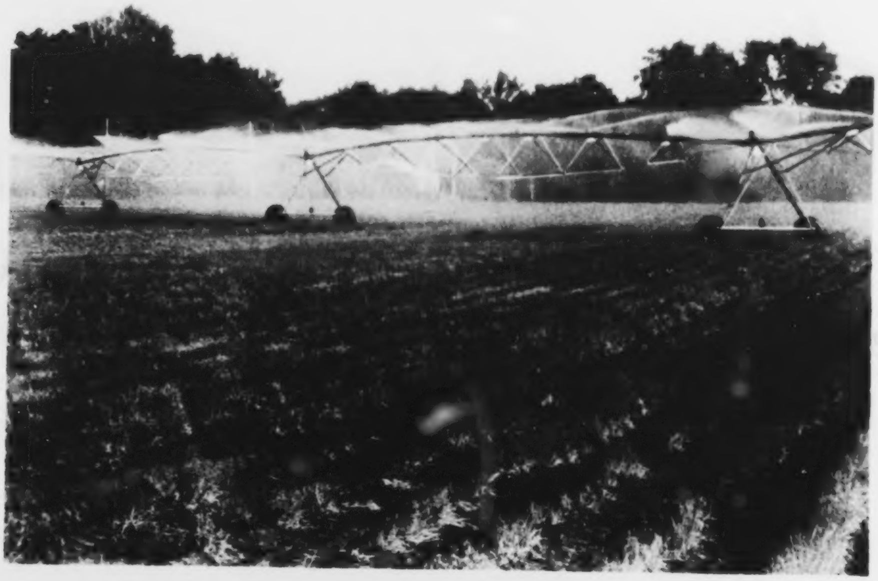
It is important to note that there isn't just one type of technology. Actually, there are several. This section introduces you to the various types of technology. See if you can get an idea as to how these differ.

Artifacts: We often think of technology as something associated with tools, machines or appliances of some sort (e.g., a bow and arrow, a power saw, a canoe, a jet engine, an electric clothes dryer, a toaster, a telephone, a computer, etc). Objects classified as this type of technology are often referred to as artifacts (or tools). Some objects within this classification, like a hoe used in planting or in cultivating a garden, are very simple artifacts. Others, like an electron scanning microscope are extremely complex. Both are good examples of technological applications. But, they represent only one type of technology. What are the other types?

Technological Processes: These technologies represent a sequence of activities designed to accomplish a particular end. They arise out of basic scientific research. Remember Pasteur? Of course, the process of pasteurization is named for him. He started applying pasteurization to the French wine industry in order to better preserve its wines. However, as you probably know, pasteurization is now applied to milk in order to reduce the number of microorganisms in it and to make it safer to drink.

Other examples? Fermentation is another example. This process arises out of basic research done originally with yeast. It is used, again, in the wine industry and in the production of vinegar. The canning of fruits and vegetables for human consumption—even the production of dog and cat food—is a technological process. Even psychoanalysis is an example of a technological process coming out of the basic research done by Freud and others. Technological processes include the processes and procedures for accomplishing tasks. There are many of them. Can you think of others?

Above: Using a simple hoe to plant field corn as the pioneers did. (1850's Home Place, Land-Between-the-Lakes, Kentucky/Tennessee). Photo courtesy H. Hungerford.



An irrigation system used in the growing of onions on a truck farm in northern Illinois. This irrigation system is, really, a part of a larger technological production system. A carefully planned sequence of events leads to the harvest of onions. You should be able to infer some of these steps from the photograph. Photo courtesy H. Hungerford.

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Technological Production Systems: These technologies include the components of a system which produces something. For example, if you were going to build a motorcycle, you would need to establish some sort of assembly line in order to put the parts together so you could end up with a functioning motorcycle. The assembly line represents a "technological production system."

If you wanted to start a publishing business and print newspapers, you would need to develop a production system. The same holds true for the production of food crops which demands a sequence of activities designed to produce that crop. This technology employs the human or physical resources needed for the production of something. And these resources are usually used in some sort of sequence.

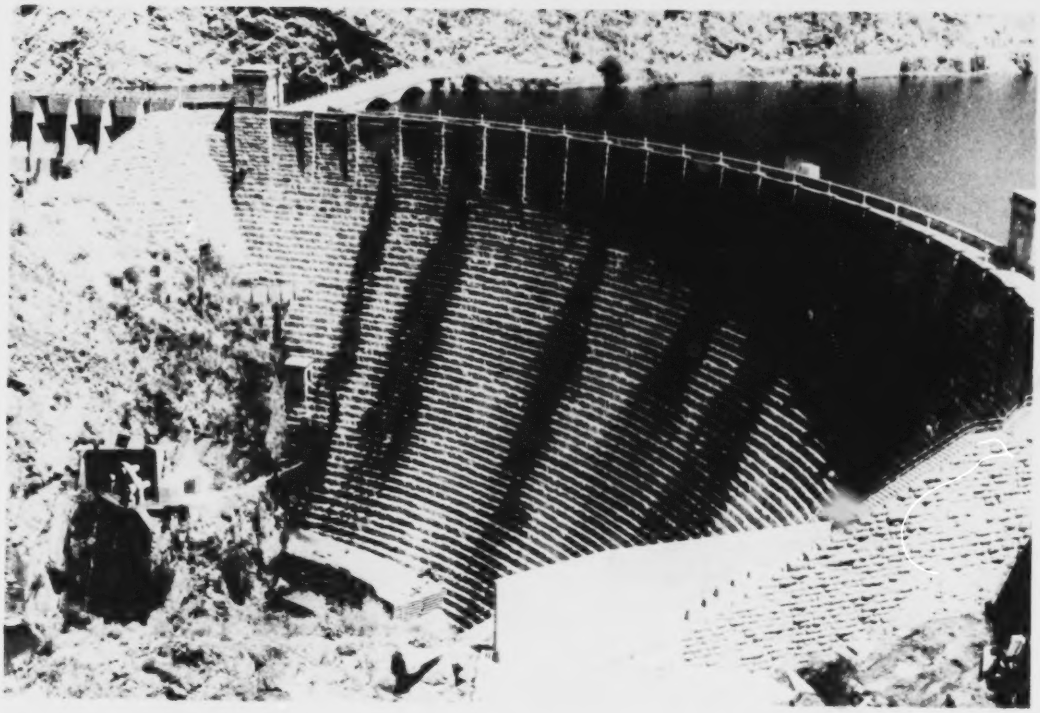
Technological "Use" Systems: This is a bit tricky, but let's define this type of technology as any system that uses combinations of technologies to accomplish a particular task—something that one person would have difficulty accomplishing alone.

How do you (or your parents) get mail every day? The U.S. Postal Service has a system developed for receiving, transporting, and delivering letters, packages, etc. This is an excellent example of a technological use system. This system consists of humans working cooperatively, machines (artifacts) to sort and transport the mail, and processes such as zip codes, postage rates, etc.

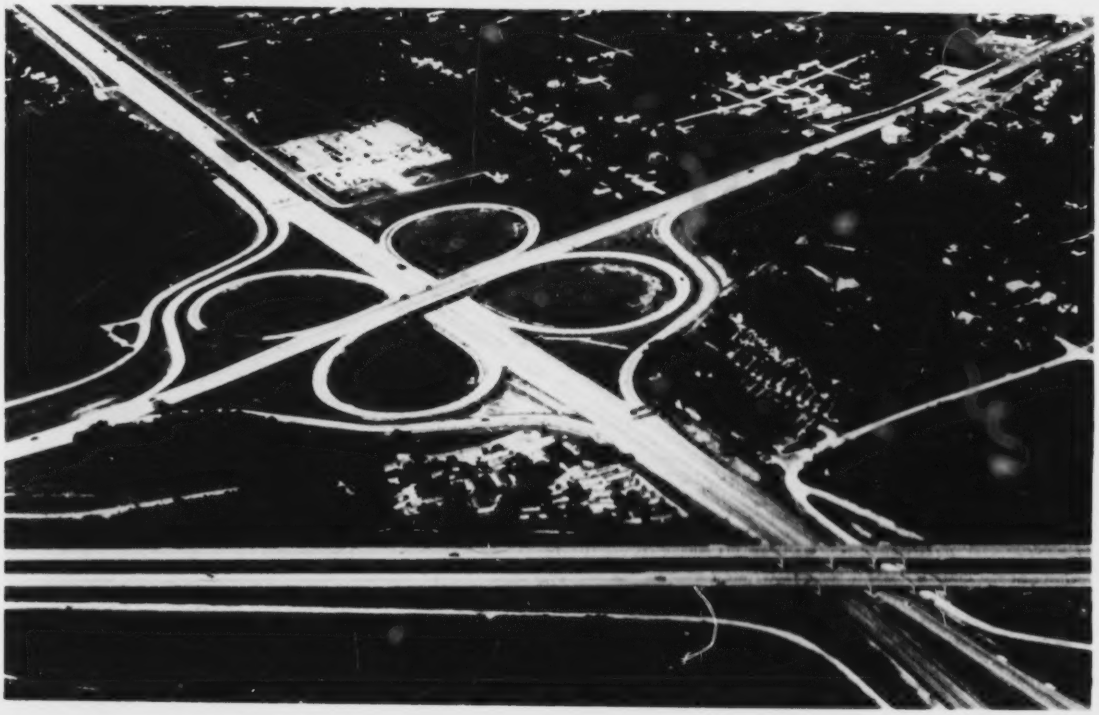
Other technological use systems would include things like moving people from place to place on a subway system or on a railway system. Of course, many of these systems use artifacts (tools/machines) to accomplish the tasks for which they are designed. However, the "system" itself is designed to accomplish some task and the artifacts simply support that system.

Regardless of the kind of technology, all systems are driven by scientific knowledge of some sort—the product of science process. In turn, some of these help scientists do new and different investigations which, in turn, lead to new technologies. Also, the science—technology relationship has radically changed the lives of your parents, and you might anticipate that it is changing your life at the very moment you read this. How might this be possible?

> *Ever wonder how a fly chews its food? Or how a mosquito breathes? Using the recently introduced Cyberscope, a computer-controlled exhibition microscope, these activities and many others can be viewed up close and in living color. Currently, there are about 30 Cyberscopes around the world. . . . The Cyberscope is manufactured by Optech International Ltd. of Auckland, New Zealand, and is unique in the combination of technical innovations it employs. The company is marketing the instrument for zoos, museums, and nature centers initially, but it says the machine also has useful applications for a number of fields including medicine, biology, geology and computer manufacturing.*
>
> *Insight, May 29, 1989*



Above: Roosevelt Dam in Arizona. Below: A highway interchange near Chicago, Illinois. Both photos represent a type of technology. Can you identify the type represented by each? What is the reasoning behind your decision? Photos courtesy H. Hungerford.



Scientist or Technologist: Which? Why? Defense!

The following list of human beings are or were associated with science or technology. In some situations, they have been associated with both science and technology. Using the information you now have concerning science and technology, you and your peers can conduct some rather simple research and make some decisions about:

(1) the major contribution(s) made by the individual,
(2) whether the individual is best described as a scientist or a technologist, and
(3) why you feel the way you do (i.e., your defense for your decision).

A few of the decisions might be difficult ones but are interesting nevertheless. Your research could be written out in a short paper or given orally in five minutes or less.

Alvarez, Luis
Banneker, Benjamin
Bell, Alexander G.
Bessemer, Sir Henry
Bohr, Niels
Boyle, Robert
Braun, Werner von
Carver, George Washington
Cavendish, Henry
Copernicus, Nicholas
Curie, Marie
da Vinci, Leonardo
Edison, Thomas
Einstein, Albert
Faraday, Michael
Fleming, Alexander
Ford, Henry I
Franklin, Benjamin
Fuller, Buckminster
Fulton, Robert
Goodall, Jane
Hooke, Robert
Huang, Alice
Jenner, Edward
Lavoisier, Antoine
Leeuwenhoek, Anton van
Lister, Joseph
Marconi, Marchese Guglielmo
McCormick, Cyrus
Mendel, Gregor Johann
Morse, Samuel
Murayama, Makio
Nobel, Alfred B.
Pasteur, Louis
Ride, Sally
Watt, Robert
Williams, Daniel Hale
Wright, Orville

In this photograph, astronaut Guion S. Bluford, mission specialist, checks out the sample pump on the continuous flow electrophoresis system experiment. This is an onboard shuttle experiment designed to separate biological materials according to their surface electrical charge as they pass through an electrical field. From what you now know, would you call astronaut Bluford a scientist or a technologist? Why? Photo courtesy NASA.

A Closing Thought and a Question

Many human beings believe that the answers to our most pressing problems lie in science and/or technology. Unfortunately, the answers to our most perplexing problems lie not in science or in the demands placed on scientists—the answers lie in the ways in which knowledge is used and the manner in which human beings behave.

Every member of society should realize that science is solely an empirical, intellectual act. Science is nothing more than the processes which we can use to produce scientific knowledge and the product or scientific information generated. Science cannot solve problems; it can only provide the information for us to choose to use. Just as science bears no blame for causing human problems, it also accepts no responsibility for solving them. Humans cause their own problems, and it is up to us to find successful solutions to those same problems. It seems terribly important for teachers to help young learners understand science—what it is and both its potential and its limitations. What do you think?

When we fall into the trap of believing or, more accurately, hoping that technology will solve all our problems, we are actually abdicating the high touch of personal responsibility. Our technological fantasies illustrate the point. We are always awaiting the new magical pill that will enable us to eat all the fattening food we want, and not gain weight; burn all the gasoline we want, and not pollute the air; live as immoderately as we choose, and not contract either cancer or heart disease.

In our minds, at least, technology is always on the verge of liberating us from personal discipline and responsibility. Only it never does and it never will.

John Naisbitt
Megatrends, 1982

Chapter Two

Why Teach Science To Children?

> *The fundamental characteristic that is common to both children and science is that both are actively involved in interpreting the objects and events of the environment.*
>
> *Gerald S. Craig*

Upon completion of Chapter Two, you will be expected to be able to ...

1. ... define the term "general education" and identify characteristics of a general education which would be important for the child and society as a whole.
2. ... synthesize and communicate a definition of "scientific literacy."
3. ... explain how "scientific literacy" differs from the traditional definition of "literacy."
4. ... identify or list the four goal cluster headings found in Project Synthesis. Further, be able to describe what is meant by each of the goal cluster headings.
5. ... present a clear, concise argument for using the Project Synthesis goal clusters as a focus for preparing a sound science program for children (i.e., why do the goal clusters represent "scientific literacy" in today's society?)
6. ... write a minimum of two (2) subgoals for each of the four Project Synthesis goal clusters that would be appropriate for the elementary school (K-8).
7. ... identify, define, and defend a minimum of four science concepts which would be important for scientific literacy.
8. ... identify several instructional dividends available to the teacher who teaches an experiential science program based on the concept of scientific literacy. Further, be able to describe how these dividends have payoff for the teacher and for learners.

Teaching Science With a General Education Perspective

In our opinion, the only good argument for educating children in the first place is to provide them with a sound "general education." What is a general education? It is one which provides human beings with the knowledge and skills that will enable them to become effective and well-adjusted members of society both today and tomorrow.

This strongly implies that there must be some very generalized bodies of knowledge and skills which are important in the lives of all human beings. It also implies that the elementary school should probably not be an institution for specializing and segregating children academically in order to reach different goals for different groups. The entire premise of "general education" is one based on the notion that a common preparation for life is of paramount importance and that the components of this curriculum can be identified and operationally defined.

It follows that all major instructional areas existing in today's elementary schools are considered of value by society for general education purposes. Whether or not this is the case, one can observe that science is finding an ever increasing role in the nation's schools and, therefore, it must be considered an integral component of general education.

As important as science is, it is by no means consistent across the schools of America. Nor can we always observe science being taught. There are times when the preservice teacher—and, indeed, oftentimes the inservice teacher—finds it difficult to provide a sound argument for science instruction. In fact, science often takes a back seat to other curricular areas and does so for a wide variety of reasons. These reasons include the "back to the basics" argument, the "lack of time for science" argument, the teacher's feeling of insecurity with science, or simply a lack of motivation on the part of the teacher to provide for science instruction. The writers believe that most of the reasons for ignoring science or for questioning its value are faulty and stem from a basic lack of understanding of what science is, of its role in society, and of its impact and potential impact on young learners.

Chapter Two of this worktext, therefore, is designed to discuss science from a general education perspective and to help eliminate the faulty perspectives concerning science so often observed in both preservice and inservice teachers. Because of this, the writers ask that you carefully consider the positions which follow and the logic behind these positions. Of great importance is your professional responsibility to clarify your own understanding of science and its role in general education. Only by achieving such clarification can you teach science in order to maximize its potential for elementary school children both today and tomorrow.

Scientific Literacy - The Major Consideration

Science has had and is having a tremendous impact on humans and their cultures. Whether we like it or not, every child and every adult must be able to cope each and every day in an environment that is science and technology oriented. This fact alone is probably a sufficient argument for placing an emphasis on science in the elementary school. As meaningful as this argument may be, the writers believe that there are many other reasons for incorporating science in the curriculum. However, all of these reasons may be discussed under one overall heading. This heading is commonly termed scientific literacy. Of course, "literacy" in this context goes beyond the constraints normally placed on a definition of literacy. It is much more than being able to read and write.

The Best Definition of Literacy—Project Synthesis

Of all of the scientific literacy definitions which exist, the best one is probably contained in a document published by the National Science Teachers Association in 1981. This document—What Research Says to the Science Teacher, Vol. III—reports on a thorough research study called Project Synthesis. Project Synthesis was funded by the National Institute for Education, U.S. Department of Education. Project Synthesis was headed by a reputable science educator from the University of Colorado, Dr. Norris Harms. Dr. Harms worked with a team of 23 science educators in order to pull together and interpret existing research on the status of science instruction in the United States. This synthesis effort drew upon three major studies sponsored by the National Science Foundation and data provided by the National Assessments of Educational Progress in Science.

Project Synthesis, therefore, represents a responsible and sophisticated effort to identify major goals for science instruction in North America. The report discusses a number of different areas of science education and brings forth four goal clusters around which curriculum should be developed and instruction planned. It is these goal clusters on which we will focus here. However, before we look at these goal clusters, a note of explanation. You will see that the goal clusters are stated and described. Under each goals cluster, you will find sample educational goals. Specific instructional objectives or outcomes are also listed for each goal cluster. In no way should you consider these to be complete listings of goals and outcomes. Only the four goal clusters themselves are exhaustive.

The Goal Clusters of Project Synthesis

GOAL CLUSTER I—*Personal Needs.*
Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.

GOAL CLUSTER II—*Societal Issues.*
Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

GOAL CLUSTER III—*Academic Preparation.*
Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge, skills, and attitudes appropriate for their needs.

GOAL CLUSTER IV—*Career Education/Awareness.*
Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

The Project Synthesis group intended that these four goal clusters be used as axioms from which subgoals and statements of student outcomes (instructional objectives) would be derived at the local level for science programs, courses and assessments of educational progress in science. In this way, local education agencies would have the flexibility to operationalize citizen scientific literacy as it best fits the needs of their students. Example subgoals and outcomes that might be stated at the local school level are provided for each of the respective goal clusters.

GOAL CLUSTER I—PERSONAL NEEDS

Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.

Subgoals

- An understanding of the nature of science - what science is and what it is not;
- Concepts associated with the impact of science and technology on one's life and on society;
- The ability to use science to help solve everyday problems;
- The ability to use science in making everyday decisions;
- Valuing and persistently trying to maintain a healthy body; and
- The ability to be a successful consumer in a scientific society.

Possible Student Outcomes

Evidence that the student can:

1. . . . demonstrate specific ways in which an individual can decrease energy consumption in the home;

2. . . . use data from a variety of sources to make decisions about personal health problems;

3. . . . modify belief systems or attitudes based on new scientific evidence;

4. . . . compare technologically-related information sources and communicate ways in which they are similar and/or different; and

5. . . .apply knowledge of energy expenditures in food production/distribution to his or her consumer practices.

GOAL CLUSTER II—SOCIETAL ISSUES

Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

Subgoals

- The development of an appreciation for the potential and the limitations of science with respect to solving societal issues;
- An understanding of the relationships which exist between science and technology and of how these pursuits influence society;
- The acquisition of both the knowledge and skills needed to deal with the environmental and energy issues affecting society;
- The development of a sense of custodianship for protecting and preserving the natural world with which science is concerned;
- An understanding of the desirability of considering various alternative value perspectives concerning science-related social issues; and
- An understanding of the very real relationship that exists between quality of human life and quality of the environment.

Possible Student Outcomes

Evidence that the student can:

1. . . . compare two or more information sources related to a particular science-related societal issue and communicate likenesses and differences observed in the comparison of those information sources;

2. . . . analyze alternative solutions to science-related societal issues and correctly determine which of those solutions would best represent both a quality human life and a quality environment;

3. . . . analyze personal behaviors and communicate the cultural and ecological implications of those behaviors;

4. . . . investigate a science-related societal issue and determine what the main value perspectives (alternative viewpoints) are with respect to that particular issue; and

5. . . . communicate the effects of various drugs used to modify human behavior and the need for social controls over those which are harmful to human beings.

GOAL CLUSTER III—ACADEMIC PREPARATION

Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge, skills, and attitudes appropriate for their needs.

Subgoals

- The acquisition of major scientific ideas (theories, laws, models) and the ability to apply these concepts to daily life;
- The development of intellectual skills (cognitive processes) needed by the scientist in the pursuit of scientific knowledge;
- The development of a respect for empiricism and associated scientific attitudes;
- The knowledge that scientific explanations of phenomena are altered as a function of new evidence/data; and
- The ability to evaluate the empirical quality of information which has been gathered by experimental means.

Possible Student Outcomes

Evidence that the student can:

1. . . . observe a simple experiment and communicate whether adequate controls have been used;

2. . . . interpret data presented in the form of functional relationships such as those found on data tables and in graphs;

3. . . . infer empirically sound explanations for observed phenomena;

4. . . . communicate major observations which led to the germ theory of disease and the impact that this theory has had on biology and medicine; and

5. . . . communicate the differences that exist between empirical knowledge and other sources of human knowledge.

GOAL CLUSTER IV—CAREER AWARENESS

Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

Subgoals

- The ability to make informed career decisions related to both science and technology;
- The understanding that both genders, all ethnic groups, persons with a wide range of educational and ability levels, and persons with various handicaps can and do obtain positions in scientific and technological fields;
- An awareness of scientists and technicians as real people;
- An understanding of the role played by a broadly-based education in becoming ready for science/technology-related careers; and
- An awareness of where information on a wide variety of science/technology-related careers can be obtained.

Possible Student Outcomes

Evidence that the student can:

1. . . . observe a particular career scientist or technician and carefully examine the potential of that career in terms of a future interest in it;

2. . . . communicate why it is important for an individual working in science to be extremely curious about natural phenomena;

3. . . . communicate why careers in science can accommodate a wide variety of student academic interests;

4. . . . decide and communicate what the main issues are in selecting a particular career in science and technology; and

5. . . . communicate how careers in certain fields such as conservation, medicine, nutrition, nursing, sanitation, horticulture, pest control, etc. are related to science.

Some More Examples

As you have read, the subgoals and student outcomes listed under the four Project Synthesis goal clusters were provided as examples of content and objectives that would be appropriate. A number of these subgoals are of such importance that we will spend additional time discussing them. The subgoals we will inspect more closely are:

> An understanding of what science is and what it is not.
>
> An understanding of the relationships which exist between science and technology and of how these pursuits influence society.
>
> The acquisition of major scientific ideas (including theories, laws, and models) and the ability to apply these concepts to daily life.
>
> The development of those intellectual skills (cognitive processes) needed by the scientist in the pursuit of scientific knowledge.
>
> The development of a respect for empiricism and the scientific attitudes associated with it.

You will notice that one of these subgoals is from the Personal Needs Goal Cluster, one from the Societal Issues Goal Cluster, and three from the Academic Preparation Goal Cluster. However, these particular subgoals are probably applicable to more than one of the Goal Clusters. Please keep this in mind throughout the following discussion.

An Understanding Of The Nature Of Science - What Science Is And What It Is Not.

Science is:

- ***empirical***
- ***replicable***
- ***tentative***
- ***probabilistic***
- ***public***

As noted earlier, science is simply a special way of investigating the objects and events of the universe. It is based on a philosophy of what reality is. This philosophy dictates some rules that must be respected when humans search for scientific knowledge. A critical element of science is its **empirical** nature. Empiricism is based on observation or experimentation. Similarly, knowledge can be empirical only if it is **replicable**. This means simply that the observation or the experiment can be repeated and shown valid. Scientists also believe that scientific knowledge is **tentative**. The scientist believes that knowledge is subject to change. Interestingly, children (and some adults, too) believe that scientific knowledge has absolute truth value (i.e., not to be doubted or questioned). This is not the case at all! Most scientific knowledge is inductively derived and subject to change as a result of new observations. Much of what scientists "know" is constantly being modified as a function of new information.

In addition, scientific knowledge is usually perceived as **probabilistic**. Here, again, we see a characteristic closely allied to the tentative nature of knowledge in science. Much of what we derive from research is a function of probabilities. A tremendous amount of the knowledge in the behavioral sciences (e.g., educational research and psychology) is a function of probabilities rather than absolute, dogmatic conclusions. How often do you hear something like, "One who smokes two packs of cigarettes a day will have a greater probability of respiratory disease than. . ." This statement is based on probabilities rather than on certainties. This is what science is all about. It permits us to predict future happenings with a high level of confidence. And, finally, scientists believe that scientific knowledge should be **public**. This is an ethic which is sometimes violated by the scientific and industrial community but one which is a basic belief nevertheless. Probably the most prevalent reason for arguing for public knowledge is one closely associated with replicability. If knowledge is made public, its "goodness" or accuracy can be tested by other scientists under similar conditions.

An Understanding Of The Relationships Which Exist Between Science And Technology And Of How These Pursuits Influence Society.

- ***Science and technology support each other.***
- ***Science and technology have limitations.***
- ***Science and technology are controlled by society***
- ***Scientific knowledge has value***

Among other things, children should understand that there are striking differences between science and technology. At the same time, the child should understand that **science and technology tend to support each other** and that the relationship between the two is a close one. This is rather like looking at both sides of the coin, and it is imperative that this be done. Allied with the above, the writers firmly believe that citizens (young and old alike) must realize the tremendous **limitations of science and technology**. Far too many people tend to see science and technology as omnipotent or all-powerful, although this is totally absurd. This perception tends to permit citizens to foolishly rely on science and technology to solve many of the persistent problems facing humans. In reality, science and technology are human-controlled and capable of solving only those problems which are amenable to investigation and solution by technological means. Most of our problems must be faced squarely by each of us acting in consort with other human beings in a citizenship capacity and not by relying on either science or technology. It is imperative to help youngsters realize that they cannot abdicate their own responsibilities to science and technology.

Further, it is important for human beings to realize that the activities of **science and technology are controlled by society**. Society has certain needs, and these are often translated into demands on science and technology. These demands can be humanistically oriented, politically oriented, economically oriented, or combinations of these. Of course, a good deal of what science researches is science-oriented—science for its own sake—the search for knowledge as a function of human curiosity. This basic curiosity has led to some of the most startling discoveries ever made: the X-ray, the research leading to the theory of evolution, space exploration, nuclear fission, etc.

Closely associated with the above characteristic of science is another that deals with the **value of scientific knowledge**. Oftentimes what science discovers appears to have little merit as far as technology or society is concerned. However, time after time, seemingly valueless knowledge has turned out to be of considerable importance later on. Many, for example, believe that the nation's space program is a waste of money. The space shuttle program alone is proving this to be faulty thinking. And, what breakthroughs lie ahead in harnessing the vast amounts of energy that exist throughout the universe? Could the apparently silly research on solar winds provide us with a basically free transportation energy source down the road? Are the natural resources of the moon and Mars possible resources for us in another twenty years? Can what we have learned about the physical reactions of humans in space be converted to save lives on earth? On and on . . . The vast backlog of scientific knowledge being gained in a multitude of research studies can have tremendous consequences for the survival of the human species in the future.

The Acquisition Of Major Scientific Ideas And The Ability To Apply These Concepts To Daily Life.

- ***Cause and effect relationships***
- ***Relationships between matter and energy***
- ***Homeostasis***
- ***Asexual and sexual reproduction***
- ***Evolution***
- ***Work***
- ***Organism, Population, Community***
- ***Ecosystem***
- ***Pollution***
- ***Time-space relationships***
- ***Relativity***
- ***Behavior***

Knowledge, in part, permits us to acquire new knowledge. We see this in the process-product cycle with which you are already familiar. Knowledge also helps free us from the chains of superstition. Although there is no complete agreement on the elements of this subgoal, it is obvious that certain key concepts are of great importance. A few of the concepts which the writers and others perceive to be important follow for purposes of example.

The idea that things happen in the universe because of **cause and effect relationships** appears crucial. The cause and effect concept has a close relationship to understanding that the universe is more or less orderly, and that happenings can be predicted with high degrees of probability. Naturally, this idea should also have the impact of allaying many of man's superstitions.

Concepts dealing with the **relationships between matter and energy** also appear critical to literacy. Human beings interact with these relationships each and every day of their lives. What are the relationships? Can matter and energy be universally conserved? Are there exceptions to this conservation? What are the implications of these ideas to human beings as they interact with the environment? The concept of **homeostasis** should also be considered a key concept in the literacy dimension. Homeostasis can be defined as a state of equilibrium or a tendency toward such a state between different but interdependent elements. On the surface, this appears to be quite an idea—too difficult, perhaps, for children. Not true! A healthy organism is homeostatic. The bits and pieces of that organism are working together successfully - in equilibrium if you will. More importantly for children, perhaps, is the notion of homeostasis as it involves their environment. Are living communities becoming less and less balanced as a function of human activities? Or, are they able to sustain homeostasis? Are humans in a homeostatic relationship with the biosphere or are there severe threats to this equilibrium? The ecological implications of homeostasis are significant and of importance to every man, woman, and child on the planet Earth.

Concepts concerning both **asexual and sexual reproduction** seem appropriate for a list of key concepts. All living species must be able to reproduce themselves, or they become extinct. Further, humans are reproducing organisms. That children should understand the basic principles of reproduction seems critically important. Note that the writers are not confusing reproduction with sex education. Sex education holds a much broader amalgam of concepts than reproduction per se.

The examples stated above represent only a small number of those concepts which are often perceived as important from a literacy perspective. Others might include such ideas as **evolution, work, the organism, population, community, ecosystem, pollution, time-space relationships, relativity, and behavior.**

The Development Of Those Intellectual Skills Needed By The Scientist In The Pursuit Of Scientific Knowledge.

- ***Observing***
- ***Comparing***
- ***Classifying***
- ***Inferring,***
- ***Hypothesizing***
- ***Designing experiments***
- ***Conducting experiments***
- ***Predicting***
- ***Measuring***

When we speak of science processes we are dealing with those intellectual skills used by scientists as they go about the business of doing science. These processes are closely allied with what educators term "**critical thinking skills**." And they probably have application (transfer potential) to all aspects of human activity, which means that the processes of science can be used in problem-solving activities beyond science. However, it may well be that science education can do a great deal to foster critical thinking in the human being and help students maximize their intellectual potential. This could be the major contribution of science in the elementary school curriculum. Whether or not science contributes to critical thinking ability in students depends entirely on whether these thought processes are taught and are, therefore, actualized. This is not an easy task, but it is certainly possible! Because an entire chapter in this worktext deals with science process, the writers will provide only a generalized description of these here.

The science process skills include such intellectual activities as **observing, comparing, classifying, inferring, hypothesizing, designing and conducting experiments, predicting, and measuring**. If you learned in school that there was such a thing as a "scientific method", you will be quick to note that many of these processes were referred to as part of that method. Today, however, most science educators take the position that there are many methods in science and that different scientific activities utilize different sets of processes.

The Development Of Scientific Attitudes

- ***Basic curiosity***
- ***Demand for verification***
- ***Suspended judgment***
- ***Empirical logic***

Certain values operate in science. These values are reflected in the more commonly held attitudes of scientists as they engage in research. Some of these values relate directly to the logic behind empiricism. Others are values held by the individual who is motivated to be involved in science itself. **Basic curiosity** is one of these values and is closely allied to our longing to know and understand. This attitude is often based on the premise that knowledge has considerable value and that empirical inquiry should be undertaken to obtain that knowledge. Another value is that associated with the **demand for verification**. A scientist often rejects knowledge that cannot be supported with hard data. At the very least, the scientist **suspends judgment** on a finding or theory until enough data are available to lend substantial support for the new knowledge.

In addition, most scientists have a sincere respect for **empirical logic**. Here the scientist insists that conclusions drawn from scientific work be based on a logical frame of reference with respect to available data. At the very simplest level, this characteristic is demonstrated by the insistence that an inference drawn from an observation be based on the logic of the situation rather than on intuition. In this way, scientific knowledge differs from dogmatic or intuitive knowledge. And, this is a difference that is critical to all of the activities of science. It is this, perhaps as much as any other single thing, that separates science from less empirical intellectual pursuits.

A Scientifically Literate Person: A Definition

Using the Project Synthesis goal clusters as our model, we can define a scientifically literate individual as:

(1) One who can use science for improving his/her own life and for coping with an increasingly technological world
- Has an understanding of what science is and is not,
- Values and tries to maintain good physical and mental health,
- Has the ability to be a successful consumer.

(2) One who can deal responsibly with science-related societal issues
- Understands the potential and limitations of science and technology for resolving societal issues,
- Has knowledge of a number of science-related societal issues and the alternative value perspectives involved in these issues,
- Has both the knowledge and ability to make sound decisions and deal responsibly with science-related societal issues.

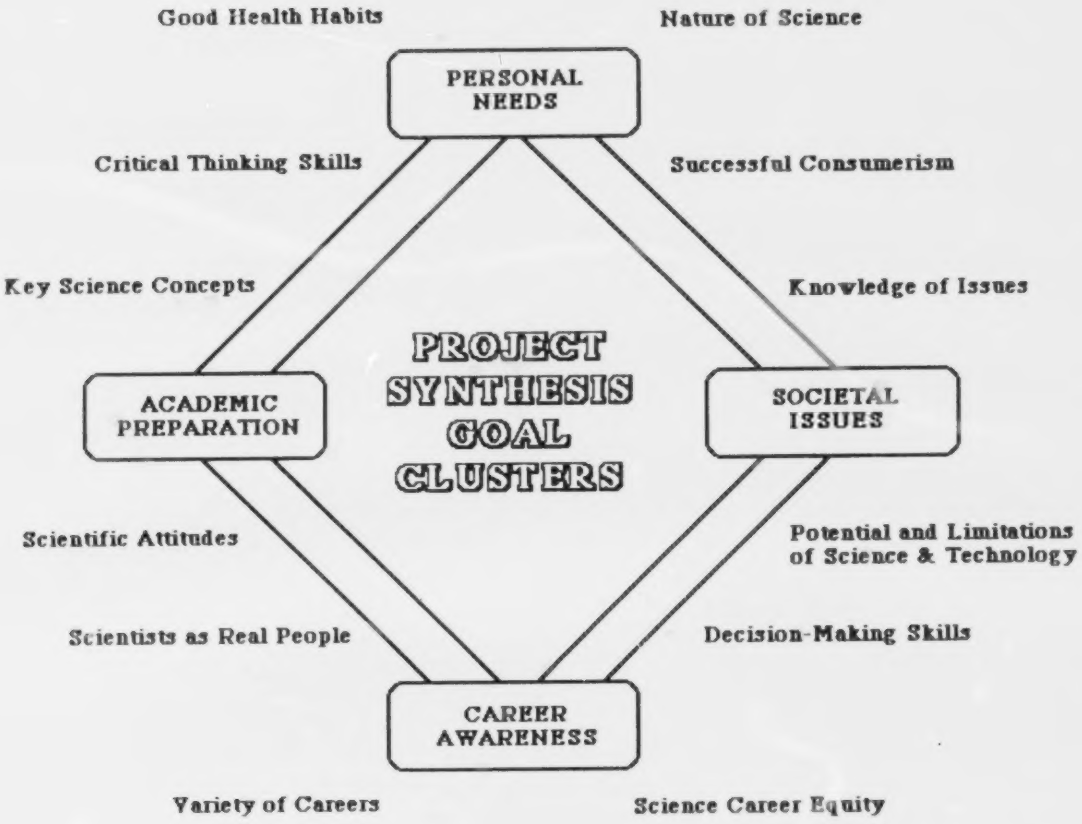
(3) One who has acquired the academic knowledge, skills, and attitudes appropriate for the pursuit of science
- Understands major scientific ideas and can apply them to daily life,
- Has developed and can utilize critical thinking skills (scientific problem solving skills),
- Has developed and exhibits scientific attitudes.

(4) One who is aware of the nature and scope of a wide variety of science-related careers open to students of varying aptitudes and interests
- Has an awareness of scientists and technicians as real people,
- Has an awareness of a wide variety of science and technology related careers,
- Understands that both genders, all ethnic groups, persons with a wide range of educational and ability levels, and persons with various handicaps succeed in scientific and technological fields.

The science educators who worked on the elementary school portion of Project Synthesis held the view that all four of the goal clusters should be emphasized in the elementary school. The Project Synthesis authors also believed that science should excite the child's natural curiosity, foster an interest in the student's environment and in the human organism itself, and provide opportunities for actually doing science in the classroom. They felt that this was the only way in which the goals of science education could be realized.

The challenge of Project Synthesis is an imposing one but one with which the authors of your worktext agree emphatically; and will use throughout this worktext. These goals also demand a teacher who is committed, well trained, and unafraid to learn along with the children. Can you be this kind of a professional? Only you can answer this question.

A MODEL OF SCIENTIFIC LITERACY


Good Health Habits
Nature of Science
PERSONAL NEEDS
Critical Thinking Skills
Successful Consumerism
Key Science Concepts
Knowledge of Issues
PROJECT SYNTHESIS GOAL CLUSTERS
ACADEMIC PREPARATION
SOCIETAL ISSUES
Scientific Attitudes
Potential and Limitations of Science & Technology
Scientists as Real People
Decision-Making Skills
CAREER AWARENESS
Variety of Careers
Science Career Equity

Other Considerations of Scientific Literacy

Since Project Synthesis in the early 1980s, scientists and educators have produced a number of documents and recommendations focusing on education reform. Still other projects and documents have included a focus on reform in science education. You will see several of these projects described in Appendix A: A Short History of Elementary Science Methods in the United States. On the following pages, you will find several recommendations for or definitions of scientific literacy. Sources for the complete documents are provided at the bottom of this page, in case you wish to examine any more closely.

We suggest you select one of these recommendations for scientific literacy and compare its view with that of Project Synthesis. Your instructor may wish to make this a class assignment with students or groups of students presenting the various definitions of scientific literacy and comparing each to that of Project Synthesis. In your analysis, try to specify the following comparisons:

1. In what ways are the two conceptualizations similar?

2. In what ways are they different?

3. What would you consider to be the strengths of each approach ? What are the weaknesses?

4. Would proponents of the two approaches find themselves in basic disagreement, or would they have much in common? Please provide your rationale for answering the way you did.

Harms, N.C. & Yager, R.E. (1981). *What Research Says to the Science Teacher, Volume Three: Project Synthesis.* Washington D.C.: National Science Teachers Association.

Turning Points: Preparing American Youth for the 21st Century: the Report of the Task Force on Education of Young Adolescence. (1989). Washington, D.C.: Carnegie Council on Adolescent Development.

Science For All Americans: A Project 2061 Report on the Literacy Goals in Science, Mathematics, and Technology. (1989). Washington, D.C.: American Association for the Advancement of Science. Also, *Benchmarks for Science Literacy.* (1993). New York: Oxford University Press.

National Science Teachers Association Handbook. 1992-93. Washington, DC: National Science Teachers Association. Also, Yager, R.E. (Editor). (1993). *What Research Says to the Science Teacher, Volume Seven: The Science, Technology, Society Movement.* Washington D.C.: National Science Teachers Association.

National Research Council. (1994). *National Science Education Standards (Draft Copy).* Washington, DC: National Academy Press.

Turning Points - Preparing American Youth for the 21st Century

In 1989, The Carnegie Council on Adolescent Development brought out what has become known as "The Carnegie Report," an effort to reshape education for the young adolescent (10-15 years of age). Since these ages fall within the traditional parameters of the elementary school, substantial consideration should be given to this report. The Report does not specifically address science literacy, but it does looks at general education goals in terms of " . . . the 15-year-old who has been well served [by education] in the middle years. . . ." Below you will see an abbreviated look at these goals. According to the Carnegie Report:

Our 15-year-old will be:

> **An intellectually reflective person;**
> *The young adolescent is maturing intellectually at a significant rate. Our youth will be able to analyze problems and issues, examine the component parts, and reintegrate them into either a solution or into a new way of stating the problem or issue. . . .*
>
> **A person en route to a lifetime of meaningful work**
> *Our young adolescent will begin to understand work as both the means of economic survival and an important source of one's identity. The youth will be increasingly aware of career and occupation options, not feeling bound by restrictions of race, gender, or ethnicity. . . .*
>
> **A good citizen**
> *Our young adolescent will be a good citizen . . . our 15-year-old will accept responsibility for shaping and not simply being shaped by surrounding events. Central to demonstrating good citizenship is a youth who is a doer, not just an observer. . .*
>
> **A caring and ethical individual**
> *Our 15-year-old will not only have learned the capacity to think clearly and critically, but will also have learned to act ethically. . . .*
>
> **A healthy person**
> *The 15-year-old we envision will be physically and mentally fit. Our 15-year-old is a thinking, productive, caring, and healthy person who takes seriously the responsibility of good citizenship."*

From *Turning Points: Preparing American Youth for the 21st Century: The Report of the Task Force on Education of Young Adolescence.* (1989). Washington, D.C.: Carnegie Council on Adolescent Development.

Project 2061 - Science For All Americans

Science for All Americans consisted of a set of recommendations developed by the National Council on Science and Technology Education. This group of scientists and educators was appointed by the American Association for the Advancement of Science and charged with identifying the understandings and habits of mind which are essential for all citizens in a scientifically literate society. *Science for All Americans* and associated reports were the products of the scientific literacy phase of Project 2061, a AAAS science reform initiative. Phase II involved teams of educators and scientists who attempted to transform *Science for All Americans* into several alternative curriculum models for the use of school districts and states. Phase III is intended to use the resources of the first two phases to move the nation toward scientific literacy. Below is the broad definition of scientific literacy utilized in Project 2061.

Scientific Literacy includes

- being familiar with the natural world and respecting its unity;
- being aware of some of the important ways in which mathematics, technology, and society depend upon one another;
- understanding some of the key concepts and principles of science;
- having a capacity for scientific ways of thinking;
- knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations;
- being able to use scientific knowledge and ways of thinking for personal and social purposes.

From *Science For All Americans: A Project 2061 Report on the Literacy Goals in Science, Mathematics, and Technology.* (1989). Washington, D.C.: American Association for the Advancement of Science.

Science/Technology/Society: A New Effort for Providing Appropriate Science for All

Science-Technology-Society (STS) education includes the various disciplines of science (biology, chemistry, physics, ecology), and other disciplines commonly considered outside the science arena (the social sciences, ethics and philosophy, literature, etc.). Since the early 1970s, STS education has emerged as a major influence for K-12 science (and beyond). In 1990, the National Science Teachers Association, adopted a statement on STS education which included the following literacy definition.

The scientifically and technologically literate person:

- uses concepts of science and technology as well as an informed reflection of ethical values in solving everyday problems and making responsible decisions in everyday life, including work and leisure
- engages in responsible work and civic actions after weighing the possible consequences of alternative options
- defends decisions and actions using rational arguments based on evidence
- engages in science and technology for the excitement and the explanations they provide
- displays curiosity about and appreciation of the natural and human-made world
- applies skepticism, careful methods, logical reasoning, and creativity in investigating the observable universe
- values scientific research and technological problem solving
- locates, collects, analyzes, and evaluates sources of scientific and technological information and uses these sources in solving problems, making decisions, and taking actions
- distinguishes between scientific and technological evidence and personal opinion and between reliable and unreliable information
- remains open to new evidence and the tentativeness of scientific/technological development
- recognizes that science and technology are human endeavors
- weighs the benefits and burdens of scientific and technological development
- recognizes the strengths and limitations of science and technology for advancing human welfare
- analyzes interactions among science, technology, and society
- connects science and technology to other human endeavors, e.g., history, mathematics, the arts, and the humanities
- considers the political, economic, moral, and ethical aspects of science and technology as they relate to personal and global issues
- offers explanations of natural phenomena which may be tested for their validity

From a statement prepared by the NSTA Task Force on STS Initiatives, unanimously approved by the NSTA Board of Directors, July, 1990. (National Science Teachers Association. [1992-1993]. In *National Science Teachers Association Handbook*. 1992-93 [pp. 168-169]. Washington, DC: Author.)

National Science Education Standards

In the early 1990s, a concerted effort was undertaken for the purpose of identifying national standards for science education. This project was under the leadership of the National research Council, with funding from the U.S. Department of Education, the National Institutes of Health, the National Aeronautics and Space Administration, and the National Science Foundation. Involving scientists, teachers, science educators and others interested in science education, this nationwide effort approached culmination in late 1994, when the final draft copy of the standards was sent across the U.S. for review. A final publication was anticipated in late 1995. The document addresses standards for science teaching, professional development of teachers of science, assessment in science education, science education content, science education programs, and science education systems.

The goals for science education that underlie the National Science Education Standards are to educate students to be able to:

- use scientific principles and processes appropriately in making personal decisions;
- experience the richness and excitement of knowing about the natural and understanding the natural world;
- increase their economic productivity; and
- engage intelligently in public discourse and debate about matters of scientific and technological concern. (p. I-5)

The National Science Education Standards provided the following definition of scientific literacy, along with further elaboration (p. I-12):

> *Scientific literacy: Scientific literacy is the knowledge and understanding of scientific concepts and processes required for participation in civic and cultural affairs, economic productivity, and personal decisionmaking.*
>
> Scientific literacy means that a person can ask and find or determine answers to questions derived from curiosity about everyday experiences. It means the ability to describe, explain and predict natural phenomena. It means the ability to read, with understanding, articles about science in the popular press and engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A scientifically literate person should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

National Research Council. (1994). *National Science Education Standards (Draft Copy).* Washington, DC: National Academy Press.

A Second Consideration - Dividends for the Science Teacher

In the opinion of the writers, there is as much potential payoff for teachers in the teaching of science as there is for the students engaging in it. The unfortunate aspect of this opinion is that this payoff is often not identified by teachers and, therefore, remains unclaimed in the classroom.

There is no question about the hard work involved for the teacher who teaches an experiential, hands-on science program for children. It is much, much easier to ignore science or to relegate it to a "let's read about science" type program. For those teachers who are willing to expend the energy necessary to provide a hands-on program, there can be some payoffs that are extremely beneficial. A brief discussion of some of these follows. Several of these so-called "payoffs" will be dealt with in more detail later in the worktext.

Hands - on science is motivational.

An experiential science program is normally very **motivational** for students. This is understandable because in a hands-on situation students are "doing" instead of reading and/or writing about science. Since several modern science programs are highly inductive in nature, science is also a time of discovery or **learning by doing**. There is a definite motivational potential here for many students because they are actively involved in the learning process.

Teachers who have been teaching from the textbook and have, for one reason or another, switched to a hands-on approach, have found it difficult to return to the textbook as the principle focus for the science program. Once having experienced the doing of science, students are very reluctant to go back to a reading-oriented program.

Science as a content vehicle has potential for skill development in reading, social studies, language arts, and mathematics.

Those teachers who make a practice of approaching the educational experience from an interdisciplinary perspective find that science content is an excellent vehicle for use in other content areas. Science as a content vehicle has potential for **skill development** in reading, social studies, language arts, and mathematics. Students are given an opportunity to draw upon their science knowledge for the development of experience charts in reading, various communication activities in the language arts, and in problem-solving in mathematics. Because most **children seem inherently interested in many science topics**, they are prone to utilize these interests in the development of skills in other areas to a much greater extent than if the content used is of only passing interest. Science subject matter is also generally free of age restrictions. Research tells us that young children are extremely interested in animals and that this interest tends to hold up well into the middle school years. Other topics are also well-suited for use as content vehicles (e.g., space exploration, fossils, prehistoric life, earthquakes and volcanoes, and reproduction) (in the adolescent years).

Teachers who supplement their regular textbook fare with reading, language, or math activities drawn from science are sometimes amazed to find the children **gain a vocabulary** which would generally be thought to be much too advanced for students of their ages. Why would this be the case? It's probably a matter of the children understanding the concepts involved in the content being used. When this is the case, children are not normally too concerned about the difficulty level of the words involved. In other words, with respect to vocabulary, the children have "intellectual pegs to hang their memories on." In this situation, vocabulary development seems to become almost automatic instead of the typical drudgery so often associated with it.

The writers of your worktext are reminded of the first grade teacher who was using fossils as a content vehicle in reading via the experience chart method. Her students had handled fossils and had seen a filmstrip on fossilization and of scientists studying fossils. She reported that, during the writing of the experience chart, the students wanted to use the word "paleontologist" in their story. Further, she reported, "I would have used the word without hesitation except that I couldn't spell it!"

The writers have already mentioned the **transfer potential of those critical thinking skills** that can be taught with science. For teachers who are sincerely committed to teaching critical thinking, science may well be the most important tool at their disposal. This is not because science is the only area in which critical thinking can be taught. It is simply because there are probably more programs available for doing this in science than in any other content area. Of major importance, however, is the very real potential for helping students learn how to transfer these skills to other content areas (e.g., social studies, language arts, and math). The teacher who is teaching science process skills (critical thinking) in science and who helps students see how these same skills can apply to problem-solving situations in other content areas, is probably the teacher who is truly helping children become **more capable problem-solvers** (i.e., critical thinkers). Therefore, the idea of teaching science process for the sake of science learning is only the beginning in the classroom where the teacher recognizes the need for critical thinking in other content areas as well.

If you are committed to teaching critical thinking, science may well be the most important tool at your disposal.

. . . demand that every citizen have a basic and functional understanding of the products of science—the concepts, the principles and the facts; and be able to understand and use the process of science—the modes of thought, the attitudes of mind, the tactics and strategy, and the appreciations . . . . This goal can be achieved through the schools in every hamlet and city across the Nation. It can be realized, however, only as it is initiated by local effort and grows up from the grass roots. It must have the support of every citizen in every local community. It will require a concerted and organized effort, but these costs are low when weighed against the realization that this kind of education in science may be basic to our survival.

Ellsworth S. Osbourn 1961

Conditions Necessary For An Effective Elementary Science Program

As you can see, an effective elementary science program can be an exciting and productive venture for both the students and the teacher. Indeed, such a program can open up new worlds to the students and offers tremendous potential for rewards for the dedicated teacher. What might the elementary teacher and faculty use as guides in designing and implementing an effective elementary science program?

The authors have attempted to furnish a number of guidelines below. Some of them will be familiar to you, as they refer to information found in Chapters One and Two. Others will represent new ideas—ideas that will be elaborated on in the following chapters. Read each of these guidelines carefully, and reflect on why it might be important in designing an effective science program.

- 1. The science program should be considered an integral part of the general education of all children in that it focuses on the development of scientifically literate human beings.

- 2. Adequate time should be provided for the science program; no less than 150 minutes per week should be scheduled for science for all grade levels in the elementary school. Further, teachers should recognize the value of science as a content vehicle in a number of other curricular areas, and should use science wisely for that purpose.

- 3. The science program should be evaluated continually in terms of whether it is meeting its goals and whether it is meeting the general education needs of the students.

- 4. The science program should teach both cognitive skills (science processes) and important conceptual knowledge. In addition, the teaching of these skills and concepts should encourage their transfer to new and unique situations of importance to the students.

- 5. The science program should be experientially oriented whenever possible. Students must have an opportunity to DO SCIENCE.

- 6. The science program should enable each student to develop accurate concepts of what science is and of the scientist as a human being.

- 7. The science program should enable each student to develop accurate concepts of the tremendous impacts which science has had on society and of the limitations and potential of science in solving many personal and social problems.

- 8. The science program should provide for a wide distribution of students' abilities (i.e., it should permit all students to be successful in meeting instructional objectives in science).

- 9. The science program should reflect specific instructional objectives, and these objectives should be communicated to students and used in evaluating them.

- 10. The science program should provide students with a set of attitudes that will encourage them to use the knowledge and skills of science in coping with both personal and social problems.

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Chapter Three

The Process Side of Science

Subsequent to your interaction with Chapter Three, you will be expected to be able to. . .

1. ... logically defend the following statement: In order to maximize a human being's ability to think critically, education must provide that individual with operational models of specific intellectual skills and offer him/her an opportunity to use these in as many different situations as possible.

2. ... provide a set of arguments for the incorporation of instruction in intellectual processes as part of an elementary science curriculum.

3.(*) ... demonstrate your ability to make scientific observations. Further, you will be expected to be able to identify which senses you used in making discrete observations, to classify observations (data) as qualitative or quantitative, and to distinguish between observations and inferences.

4. ... defend the idea that conscious mental internalization must take place for an observation to be made.

5. ... operationally define each of the following science processes and distinguish between them: observing, comparing, classifying graphically, controlling variables, and experimenting.

6. ... cite at least two functional, cultural uses of classification other than formal scientific taxonomy.

7. ... distinguish between the three basic types of classification schemes (i.e., multistage, binary, and serial ordering).

8. ... defend the basic assumption that classification schemes are arbitrary (i.e., they depend largely on a person's perspective of his/her universe for immediate needs).

9.(*) ... (a) formulate and defend an alternate and logical classification scheme for a set of previously classified objects, and (b) formulate and defend a classification system for a new set of objects.

10.(*) ... demonstrate the ability to transfer science processes to new and unique situations.

11. ... explain how the inferring process is related to a person's perception of the environment as well as the knowledge he/she holds concerning the environment.

NOTE: Several of the objectives have an asterisk (*) in front of them. These objectives will be demonstrated specifically during a laboratory or through interpretive work done in class. The student should also be able to use these same processes on a quiz in a transfer situation.

12.(*) ... prepare logical inferences based on observations of physical phenomena.

13.(*) ... write increasingly accurate inferences based on the acquisition of new information.

14.(*) ... write logical hypotheses which are consistent with the scientific rules of hypothesizing.

15.(*) ... produce testable, written hypotheses based on observations of physical phenomena.

16. ... explain why the hypothesis serves as a focal point of scientific research.

17.(*) ... prepare a generalization based on an interpretation of a set of recorded data.

18.(*) ... demonstrate the ability to accurately collect data.

19.(*) ... demonstrate the ability to accurately interpret data.

20.(*) ... transfer descriptive and/or tabular data to a graph, correctly applying the basic rules of graphing to the task.

21. ... distinguish between the function of a bar graph and a coordinate graph.

22.(*) ... produce a logical conclusion and inferences based on ecological data.

23.(*) ... describe or identify the differences between dependent, independent, and controlled variables.

24.(*) ... identify dependent, independent and controlled variables in an experiment or problem setting.

25. ... correctly identify relationships between variables (i.e., direct, indirect (inverse) and constant relationships).

26.(*) ... design an experiment to test a hypothesis.

27.(*) ... demonstrate the ability to control and manipulate variables in an experimental setting so that a hypothesis can be tested.

28.(*) ... make correct decisions regarding the validity of a hypothesis on the basis of experimental evidence.

29. ... analyze the pendulum process activity and identify those discrete science processes used in that activity.

30. ... define a discrepant event and discuss its role in scientific problem-solving.

31. ... identify the correct sequence of events which occur in the scientific solution of a problem (e.g., the pendulum activities).

32. ... analyze any of the process models used in this chapter and describe how that activity supports the concept that science is a combination of process and product.

The Process Side of Science

The process side of science deals specifically with the doing aspect of science—the use of intellectual skills to obtain answers sought from the universe. It makes no difference whether the process is used by a child making a simple observation of a part of his environment or an astronomer searching for evidence of celestial bodies not revealed by photographs, as long as the investigation is empirical. The simplest critical observation may yield as valuable data as the most complex experiment. In fact, the scientist must continually use observation as he experiments. Knowledge of hypothesizing and inferring may well help a student cope more successfully with many academic and daily situations that seem to demand problem-solving skills. Knowledge of what constitutes a rational conclusion or a logical recommendation may influence a person's decision-making in a fruitful direction rather than a debilitating one. Herein lies one of the prime reasons for helping children achieve the skills of scientific inquiry—it may be that an ability to think critically is the most liberating phenomenon of man's culture.

Should the reader find this rationale for teaching science process unacceptable, perhaps a brief commentary in terms of an anecdotal defense for process education would be appropriate. Inductive and deductive reasoning are themselves examples of thinking processes. In the same context, legitimate concept development serves the individual by enabling him to mediate stimuli impinging on his senses from the universe around him. The entire business of inductive conceptualization is, in actuality, a highly functional form of classification. And, classification is one of the basic process components of science. Man uses certain kinds of classification skills each and every day of his life, but the most important use may well be his ability to classify and meaningfully incorporate new life experiences into his intellect (i.e., conceptualization).

If man is so proficient in the use of classification in concept formation, why should we bother to promote its inclusion in science education? But wait, who said that man was able to maximize his classification ability automatically? Indeed, we have evidence to support the notion that he cannot! Further, we have considerable evidence to support the idea that man increases in his ability to classify when he better understands the constructs of classification itself. Education can help him do this, quickly and efficiently. If that isn't enough, we also have evidence to support the contention that man's ability to classify is increased when we specifically train him to sharpen his cognitive powers of observation and comparison. Why? Because these are basic and simple prerequisite skills necessary for effective and empirically defensible classification behavior.

Similarly, there is considerable evidence to support the assumption that once a person has had training in a specific aspect of critical thinking, he can *transfer* this cognitive ability to a new dimension, particularly if the new situation appears to necessitate the same kind of thinking as that on which the training was conducted. Further, modern educators of repute firmly believe that the student can be specifically taught mechanisms for transferring critical thinking which permit him to apply his ability to a wide range of new and unique situations. For example, once a child has learned *how to measure* temperature of water (measurement being a scientific process), he can measure the temperature of many other substances (e.g., air, his body). When a child learns *how to construct a graph* and *how to interpret data*, he can graph data in science, math, and social studies and interpret data presented in newspapers, magazines, on television, etc.

If we were to generalize a statement of paramount importance concerning the development and transfer of critical thinking skills, it would be as follows: *In order to maximize a human being's ability to think critically, education must*

1. teach him what the skills are (i.e., define the skill);
2. teach him how to perform them (i.e., provide an operational model of each specific process), and
3. offer him opportunity to practice (use) the skills in as many different situations as possible.

In these ways, the skills become part of the student; they are not easily forgotten, and can be transferred to situations other than those used as the skill teaching vehicles.

Modern science education offers one of the most powerful vehicles available for teaching critical thinking skills. This does not mean that other disciplines lack this opportunity. Science education, however, has brought process to the forefront and has designed both simple and complex vehicles for teaching cognitive skills. Hopefully, all other disciplines will eventually provide an equally significant emphasis.

An Ending Note

The authors of this worktext view critical thinking as a desirable goal for all human beings. Critical thinking is viewed as the ability to use individual process skills or combinations of these skills in *problem-solving/decision-making situations* in both school and out-of-school settings. In this chapter, you will be introduced to a variety of specific science processes—namely, observation, inferring, classifying, hypothesizing, interpreting data, predicting, communicating graphically, controlling variables and experimenting. In addition, you will have an opportunity to apply these skills in science situations. These, plus other activities found later in this worktext, should provide you with a foundation for helping children in classrooms across the nation become better critical thinkers. Hopefully, you will approach these exercises with that idea in the forefront of your mind.

> *An hypothesis is, strictly speaking, a proposition which is put forward for consideration, and concerning the truth or falsity of which nothing is attested until the consideration is completed. It is thus necessarily associated with doubt, but with doubt of a negative rather than a positive kind. With the doubt which consists of a suspense of judgment rather than with the doubt which consists of an inclination to disbelieve.*
>
> *Norman R. Campbell—1922*

An Observation Process Model

Critical observation and the subsequent *correct* and *careful communication* of observations made are the most powerful basic intellectual tools of the scientist. Basically, observation is a process of using one or more of the five senses to obtain information about objects or events. Observation and communication skills are used in a wide variety of ways in science. Further, they are integral parts of other more sophisticated processes as well (e.g., classification and experimentation). As basic, they are to be taken seriously and you are expected to demonstrate an ability to make accurate observations and communicate these clearly to others.

Observing A Candle

For starters, we are going to ask you to observe a burning candle. You will be given a candle, a piece of foil, and matches. Place a drop of wax on the foil and attach the bottom of the candle to it. Next, light the candle. Be sure to take any and all safety precautions while working with the burning candle.

In the space below, please record ALL of the separate critical observations you can make regarding the burning candle. You should also feel free to make observations before and after the candle has burned.

LIST OF CRITICAL OBSERVATIONS

Do not go on until you are directed to do so. Thank you!

A Note on Safety . . .

Safety in the classroom is an important consideration. It is especially critical during activity-based learning in which students move around the room and work with equipment.

This activity, "Observing a Candle" is one which could be used in the elementary classroom only after attending to numerous safrety concerns and precautions. Because of that, it is a good one for you to use as you start thinking about safety in the classroom.

An Assignment . . .

Prior to doing any activity, it is essential the activity be analyzed for potential hazards. Assume you have decided to do this activity with a group of sixth grade students. Analyze the activity for potential safety problems. Identify the potential safety problem and describe the precautions that should be taken. Also, you will need to generate a list of safety equipment that should be available when using both open flame and other heating elements in the classroom. Complete the "Observing the Candle: Safety Sheet" in Appendix F.

Analyzing Your Observations

There will be several tasks associated with the analysis of your observations. Let's take them one at a time and see how well you have done!

Inferring—Cheating A Bit: One of the most common errors associated with students who are making scientific observations is that of slipping in a few "observations" which are really inferences. An observation in science can only be that which is available to the observer through one of his/her senses. Any *interpretation* of an observation goes beyond this and must be called an *inference*. Please go back to your original list and cross out any "observations" which are inferences.

Assessing the Senses Used: Now that you have a final list of sorts, you might find it interesting to inspect your list to determine which senses were used in making the observations. As you know, the senses were sight (Si), touch (To), hearing (H), smell (Sm), and taste (Ta). Please code each observation on your list according to the sense used in making each observation.

Now that you have completed that task, let's determine how many times *each* of the senses was represented on your list. When you have completed that task, please determine the percentages for each sense. Record your data on the following page.

Frequency of Observations Related to Each Sense

The Sense	Number	Percent
Sight	______	_______
Touch	______	_______
Hearing	______	_______
Smell	______	_______
Taste	______	_______

Did you use one sense more than any other? Which one? Why do you suppose this is the case?

Qualitative vs. Quantitative: There remains one more analysis task for you. Observations can be either qualitative or quantitative. A *qualitative observation* is one which is descriptive in nature (i.e., only the senses were used to make the observation). It involves quality rather than quantity (e.g., the candle was blue). A *quantitative observation*, on the other hand, involves some measurement of quantity or amount. It is more precise and usually includes a reference to a particular standard of measure (e.g., the candle was 7 cm. in height prior to burning). Quantitative measurements allow for exact comparisons. Besides using instruments to measure precisely, some individuals choose to estimate or make comparisons. Although estimates and comparisons (e.g., longer than, heavier than) are still quantitative observations, they are relative and not quite as precise as specific measurements. Precise measurement should be the goal.

Go back to your original list and code each observation which is *quantitative* with a *QT*. Code the *qualitative* observations with a *QL*. When completed with this analysis, make certain that you have accounted for all of your observations.

How many of each kind did you have? How many *qualitative* (QL) ones? __________ How many *quantitative* (QT) ones? __________ Is there more of one than another? Why do you suppose this might be the case?

What Should the Rules Be?

You may not be an expert in observation after this one activity, but you should have a pretty good idea of what's involved. Let us assume that you are responsible for teaching someone else how to make good observations. What would you teach students? What would your list of "rules" or guidelines look like?

On the following page, you will find space for you to prepare a list of "Rules for Observing." Please be as thorough as possible in your analysis of this skill.

When you established rules for observation, did you consider—(l) using as wide a variety of senses as possible; (2) adding specificity by making quantitative as well as qualitative observations; (3) checking your observations with those of a fellow student so that objective rather than subjective observations are made; (4) observing before, during, and after when describing a situation where a change takes place; (5) using instruments to extend your senses (e.g., microscope, balance, thermometer); (6) communicating the observation clearly and completely; and (7) discriminating between observations and inferences?

More On Observation

The ability to observe is a basic way in which man gathers information. Observation really means more than simply using one's senses, however. One must also consciously internalize the data gathered by the senses in order for the information to be meaningful and have potential for use. If you see, touch, or hear something, and do not consciously pay attention to the stimuli (i.e., register them), you have not really observed. Internalization of stimuli is somewhat related to someone hearing but not listening, or eating but not tasting a meal.

Perhaps an example might help. Without peeking, can you correctly tell your instructor the number of windows in the classroom or the color of the hair of the classmate sitting behind you? If not, why not? It may be that although you have "seen" the windows or your classmate each time you entered the room, you have not internalized what you have seen—you have not observed! Without internalization of sensory data, there is no meaning. And, without meaningful data, there are no grounds for curiosity, thought, interpretation of our environment or incentive to investigate further.

Observations of Popcorn

In this second activity you will be evaluated on your observation skills and your application of observing rules. In particular, you will be observing popcorn and the changes it undergoes while popping. In the space provided below, list statements of observation about the popcorn: (1) before it is popped, (2) during popping, and (3) after popping has been completed. For each qualitative statement, identify the sense you used to gain the information, and for each quantitative statement, identify the instrument used to extend your sense. Only use the sense of taste with the permission of your instructor.

	Qualitative Observations (Sense)	**Quantitative Observations (Instrument)**
Before:	1.	1.
	2.	2.
	3.	3.
	4.	4.
	5.	5.
During:	1.	1.
	2.	2.
	3.	3.
	4.	4.
	5.	5.
After:	1.	1.
	2.	2.
	3.	3.
	4.	4.
	5.	5.

A Comparison Process Model

The world in which we live contains a wide variety of living and nonliving objects and a multitude of different events. As humans observe these objects and events, they begin to notice that many of them are alike while others are very different. In other words, humans *compare* the things that they observe. The ability to compare critically is another intellectual process. In a hierarchical sense, comparison can only take place after observations have been made. One must first gather observational data on the individual objects or events under investigation. The mind, then, identifies the ways in which the objects/events match (i.e., similarities), and the ways in which they are not similar (i.e., differences).

Humans use comparison in many daily life activities. Consider a trip to a supermarket where the consumer will compare prices, nutritional data, and preparation instructions of food products before purchasing items. A wise car buyer will usually compare gas mileage per gallon, warranty, engine size, repair costs, dealer service records, and price prior to deciding on an automobile.

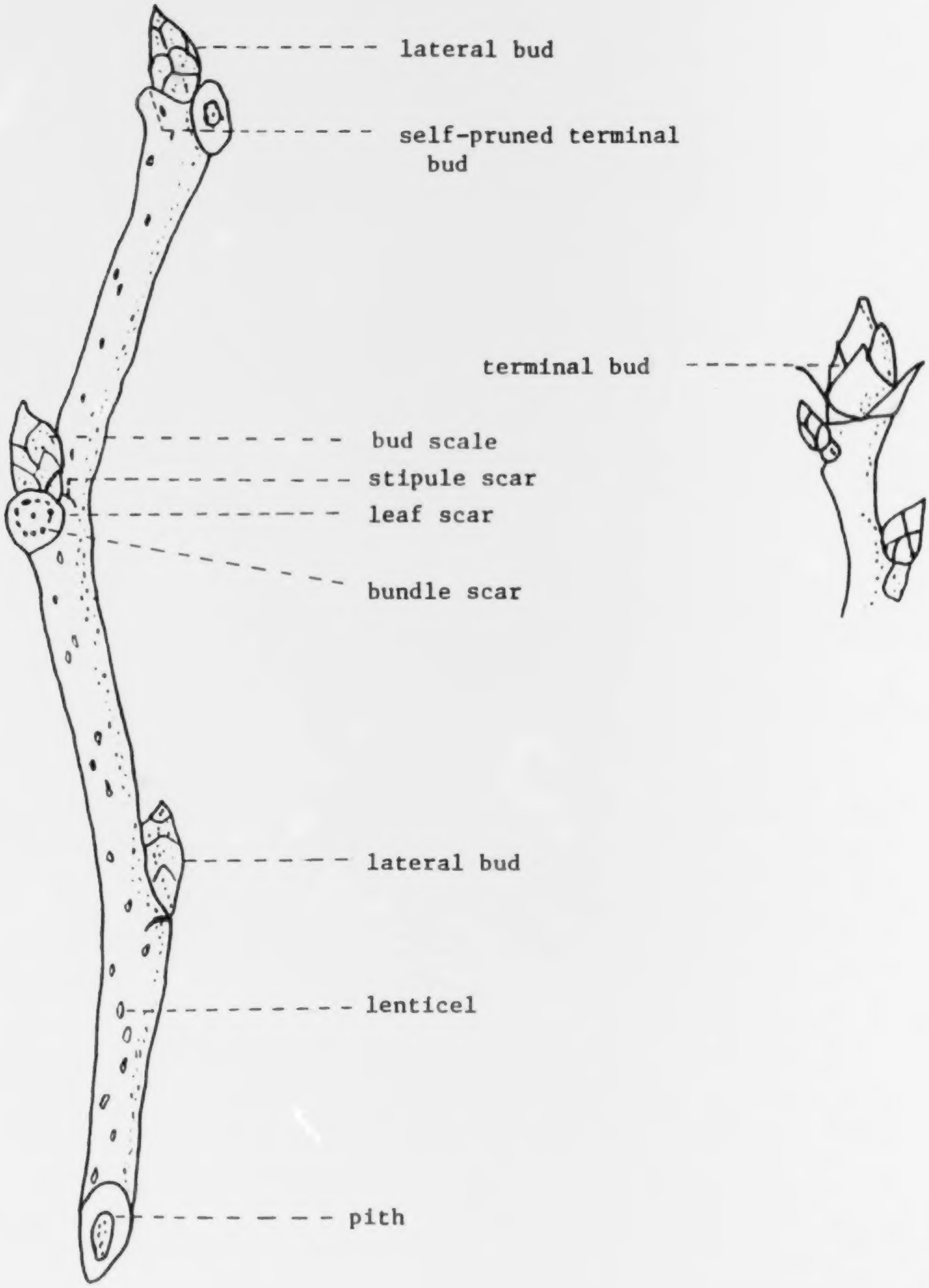
In science, comparison is an essential process. It is usually accomplished in a systematic fashion. Bacteriologists will compare cell structures of bacteria, colony color, and size, as well as optimal growing conditions as part of their research. Physicists compare temperatures, pressures and volumes of gases. Comparison is also used by scientists as they classify, experiment, interpret data, or make predictions. It, like observation, is a basic science process which can be a component of more sophisticated critical thinking skills. Because many scientists and science educators consider comparison to be an inherent part of skills such as classification and experimentation, you may not find it specifically identified as a discrete process. For our purposes, however, we will spend a bit of time with comparison as a separate process.

Comparing Winter Twigs

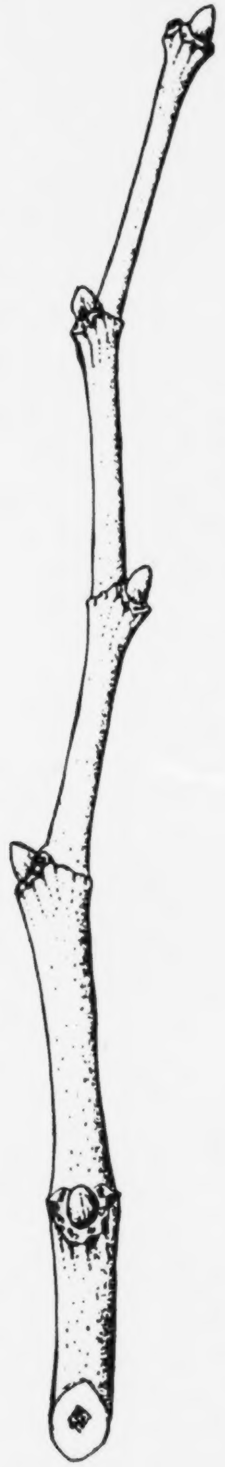
People generally do not pay close attention to the winter twigs of deciduous trees. But, for purposes of comparison, winter twigs do offer a set of clearly observable properties (physical characteristics) which are different across tree species. Because most individuals are unfamiliar with the characteristics of winter twigs, you will find a labeled drawing of a typical winter twig on the next page. The locations and names of the major twig structures have been identified to assist you in the comparison activity. Feel free to refer to it as you progress through the activity.

On the page *following* the drawing of a typical winter twig, you will find accurate artistic representations of the winter twigs of two separate tree species (i.e., sycamore and ash). Your first task is to prepare a list of the observable physical characteristics of the sycamore twig. List your observations in the space provided.

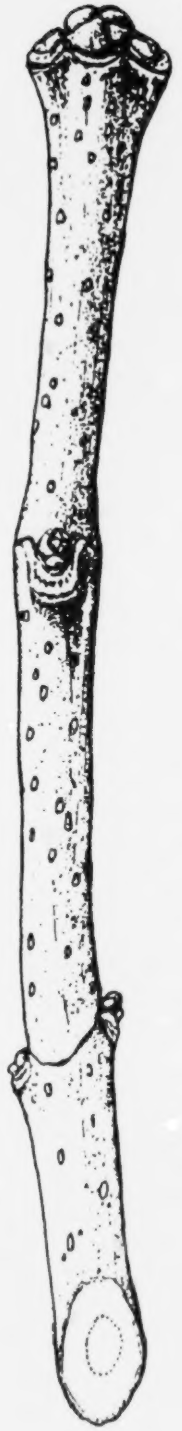
TYPICAL WINTER TWIG CHARACTERISTICS


lateral bud
self-pruned terminal bud
terminal bud
bud scale
stipule scar
leaf scar
bundle scar
lateral bud
lenticel
pith

SYCAMORE



ASH



SYCAMORE WINTER TWIG CHARACTERISTICS

1. EXAMPLE: Sycamore has many lenticels which look like small speckles.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Stop at this point. Your instructor will hold a class discussion on the sycamore observations the class has made.

Now that you have some experience with sycamore characteristics, try your hand at observing the properties of the ash twig. List your observations in the space provided below.

ASH WINTER TWIG CHARACTERISTICS

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Comparison At Last!

It should have become obvious during your observing of the ash that it was both similar to and different from the sycamore. Because you now have observational data on two different objects, you have the intellectual ammunition to proceed with comparison. In the spaces below, list the ways in which the twigs are similar and are different.

SYCAMORE AND ASH SIMILARITIES	SYCAMORE AND ASH DIFFERENCES
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

Although you could have communicated that the twigs were different at first glance, this experience should have enabled you to approach comparison systematically instead of randomly. Also, your comparisons should have been much more extensive and precise. You probably recognized more similarities than you would have initially, as individuals tend to identify and communicate differences more frequently than they do likenesses. This may occur because discrepancies seem to stimulate the senses to a greater extent than do similarities. Finally, via a discussion of the observations and comparisons, you should be starting to sort out the important twig characteristics from those which are irrelevant to the task of species description. Such abilities are the earmark of good science and are of equal value in the application of comparison to everyday tasks.

This excursion into comparison has been brief. However, subsequent activities with other scientific processes will demand your further use of comparison. More on this later!

A CLASSIFICATION MODEL

It was pointed out earlier that humans typically compare the objects and events that are observed. A step beyond this observation and comparison is the separation of these objects or events into groups that contain closely related items (those sharing a large number of similarities). The process that humans use to accomplish this grouping is called *classification*. The purpose in classification is probably twofold: (1) to impose an order on the objects and events of which humans are aware and (2) to allow the overwhelming amount of knowledge which has been accumulated to be used more easily.

Since the methods of classification are man-made, one must realize that any such system is arbitrary in nature (i.e., based on or subject to individual judgment or discretion). The validity of a classification system rests on its acceptance by society in general. In scientific classification, the validity of a system depends upon the consensus, or agreement, of the scientific community. Classification takes place in other facets of life besides science. Grocery and department stores are examples of man's classification usage. So are newspaper want ads and the yellow pages. Each is based on a logic pattern with which the human mind can cope. These systems are arbitrary, yet they are accepted because they are based on an orderly thinking pattern which is substantiated by the observations and comparisons humans make on any set of objects and/or events.

Most objects and/or events can be classified in more than one way as long as the classification system fits the data. For example, an entomologist might classify insects on the basis of their body structure (anatomy) whereas in agriculture, an economic entomologist would classify them as beneficial, harmful, or neutral in regard to man's domestic plants and animals. Another example: How do we classify movies? Of course, they are G, PG, PG-13, R, or X. But someone else might classify them according to their subject matter (e.g., love stories, westerns, musicals, science fiction). The classification scheme used is the one that fits a certain need (e.g., whether the subject matter is appropriate for children).

In summary, classification systems are created by humans to help them intellectually organize knowledge. Classification systems are arbitrary and are acceptable only if they are logical and fit the data available to the classifier. Classification systems for the same objects and/or events may vary, usually in terms of the needs of the individual(s) involved.

Learning About Attributes

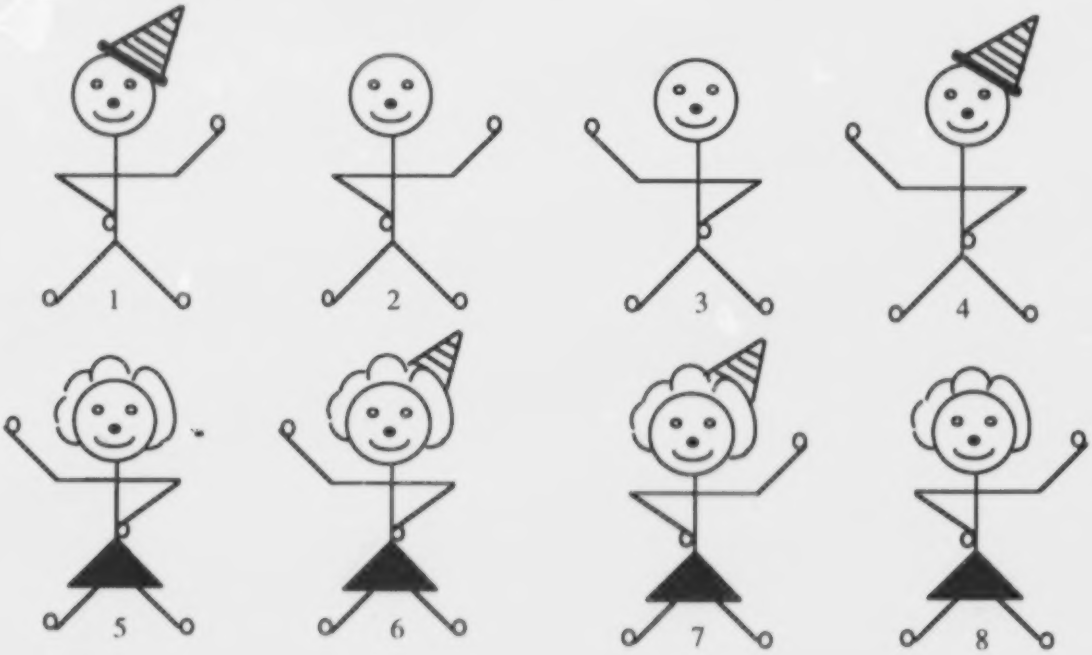
You should be getting the idea that a classification system is based on the characteristics of objects (or events). It may be noted that insects can be classified according to whether they are harmful, beneficial, or neutral. These characteristics are called *attributes*. It is on the basis of these *attributes* that we may make decisions about how to classify insects from an economic point of view.

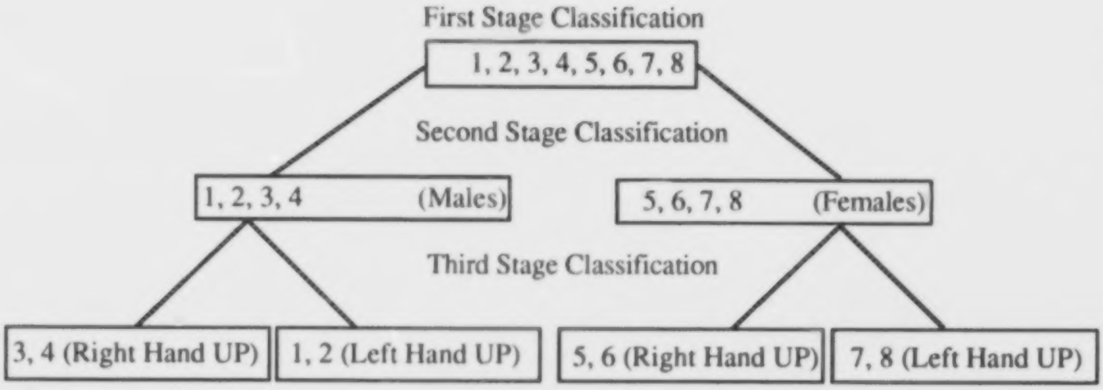
In medicine, diseases are often classified according to particular attributes. Some are classified as viral; some as bacterial. Fractures can be simple or compound. Births can be normal or breech. They can also be term or premature. The words used to categorize or classify diseases, fractures, or births are a function of the *attributes* associated with them. The attribute associated with a term birth is simply one of carrying the baby the full nine months. The attribute associated with a premature birth is a delivery of a baby which has been carried for a period of time substantially less than nine months. As in any area of science, such classifications are totally arbitrary, based on logic and a need for grouping objects or events into separate groups.

At this time we will look at some objects and identify the attributes associated with them. Let's see how well we can accomplish this.

Classifying Cheerleaders: Multistage Classification

Few people would take the time or energy to classify objects like cheerleaders. But, for our purposes here, they seem like a good and fun way to begin classifying. Below, you will find eight (8) handsome, healthy, energetic cheerleaders. You will also find that they have been classified three separate times. Each time they were classified, the classification system became more refined. This particular system is referred to as a *three-stage classification* scheme. There could have been fewer or more stages. Please observe and compare these cheerleaders and then study how these cheerleaders have been classified.




First Stage Classification
1, 2, 3, 4, 5, 6, 7, 8
Second Stage Classification
1, 2, 3, 4 (Males)
5, 6, 7, 8 (Females)
Third Stage Classification
3, 4 (Right Hand UP)
1, 2 (Left Hand UP)
5, 6 (Right Hand UP)
7, 8 (Left Hand UP)

How else might the third stage (cheerleaders) be classified?

Try your hand at reclassifying the third stage. What observable evidence do you have that will defend this new third stage?

__________ __________ __________ __________

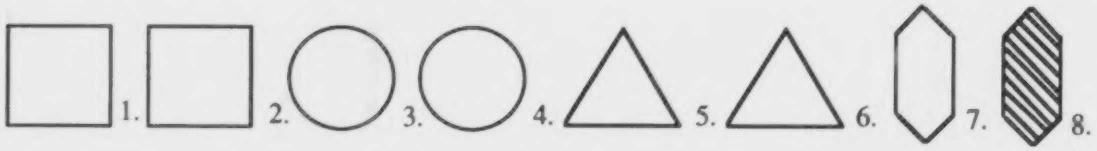
Your evidence? ____

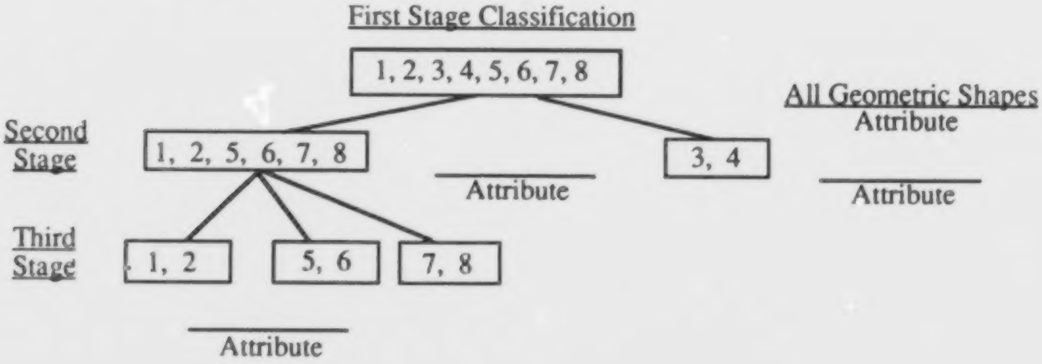
____

A Bit More Information on Classification

Far too many people, when they are beginning to learn the basics of classification, think that the second and third stages in a three-stage classification scheme must be divided into groups that contain equal numbers of items. This was exactly the case with cheerleaders. This idea about classification is not correct, however. There are many times when the classification scheme looks quite a bit different than it did for the cheerleaders.

Let's take a look at one example of a classification scheme in which the second and third stages don't look as they did with the cheerleaders. In this particular situation, we are grouping geometric shapes into a logical, but arbitrary system. What are the characteristics of the second and third stages? Write the criteria which defend the classification in the spaces provided.




First Stage Classification
1, 2, 3, 4, 5, 6, 7, 8
All Geometric Shapes
Attribute
Second Stage
1, 2, 5, 6, 7, 8
Attribute
3, 4
Attribute
Third Stage
1, 2
5, 6
7, 8
Attribute

Could the above classification' scheme be taken to a fourth stage? Why or why not?

On To Binary Classification Schemes and Their Use

Scientists often group objects and events together via classification. However, there are many occasions when there is a need to separate objects out of the groupings into which they have been classified. One of those needs is to be able *to identify* a specific object. For example, beetles are put together into one order of insects (Coleoptera). They are all classified as beetles. But, what if you want to know what kind of a beetle has been preying upon your garden cucumbers? If someone isn't around to tell you what it is, you must identify (key out) and separate just this one beetle from all other beetles. If you key it out using a specific set of instructions, you are using what is called *a binary classification scheme* the use of which is *to identify* specific objects.

The rules of binary classification are fairly simple. First, you find a characteristic (attribute) which is common to some of the objects in a set but not to the rest of them. This attribute divides them into two subgroups. Second, you select another attribute for each of the subgroups, which will further subdivide them. If you do this often enough, you will eventually have most (or all) of the objects isolated one from another. For example, a biologist might select the attribute "living or non-living" to divide rocks and minerals from plants and animals. It is important to remember that when attributes are selected, one must be sure that it divides the group so that all objects in the group fit into only one of the two subgroups.

Now let's see how this works. On an earlier page in this chapter, you will find a set of eight geometric shapes. The authors have set up a binary classification scheme for them. It follows:

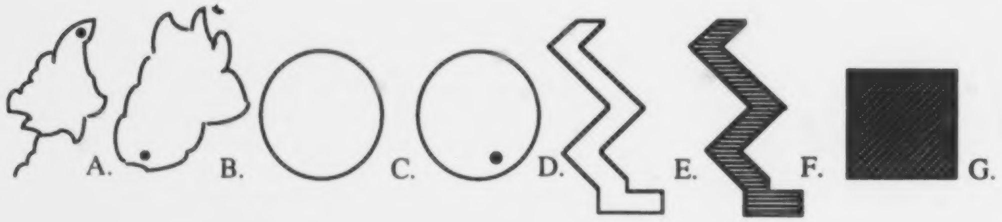
Geometric Shapes: A Key

1a.	Geo shapes with curved lines	CIRCLES.
1b.	Geo shapes with straight lines	go to No. 2.
2a.	Geo shapes with three sides	TRIANGLE.
2b.	Geo shapes with more than three sides	go to No. 3.
3a.	Geo shapes with four sides	SQUARES.
3b.	Geo shapes with six sides	go to No. 4.
4a.	Geo shapes with plain interior	PLAIN HEXAGON.
4b.	Geo shapes with shaded interior	SHADED HEXAGON.

Could this binary system have been written differently? How might it have been done differently? Would it have worked another way.? What do you think?

Your Chance To Construct A Key

Below, you will find seven (7) objects. Your task is to construct a binary classification system that will permit you to key out each of these so that you will wind up with every one separated from all others. It is hard to name these objects, so you can call them A, B, C, D, E, F and G. Use as many lines below as you need. Remember what the rules are.



1a. ____.

1b. ____.

2a. ____.

2b. ____.

3a. ____.

3b. ____.

4a. ____.

4b. ____.

5a. ____.

5b. ____.

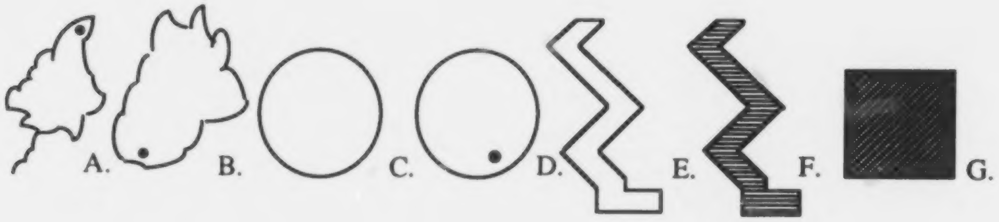
6a. ____.

6b. ____.

7a. ____.

7b. ____.

One Possible Binary Classification Scheme for Geometric Figures



1a.	Objects with shaded interiors	Go to No. 2.
1b.	Objects without shaded interiors	Go to No. 3.
2a.	Four sided objects	G
2b.	Objects with more than four sides	F
3a.	Objects with straight lines	E
3b.	Objects with curved lines	Go to No. 4.
4a.	Objects with tail	A
4b.	Objects without tail	Go to No. 5.
5a.	Object without large dot	C
5b.	Object with large dot	Go to No. 6.
6a.	Curved lines/circle	D
6b.	Curved lines/not a circle	B

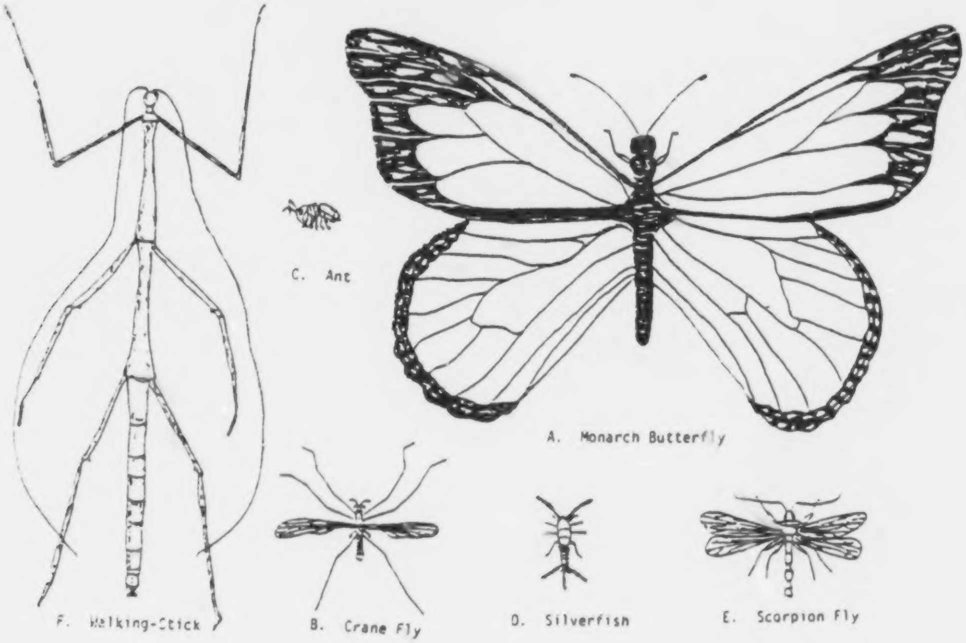
On To Serial Ordering Classification

In many instances, objects in groups can be placed in a logical order (classified) on the basis of the *extent* or *degree* to which they demonstrate a particular common attribute. This is called *serial ordering classification.* Objects might be classified as heaviest to lightest, longest to shortest, oldest to youngest, darkest to lightest, etc., depending on the classification purpose. Geologists classify minerals according to their degree of hardness. Biologists might classify insects according to the stages of their life cycle (e.g., egg, larva, pupa, adult). Serial ordering may well be the least complex of the four classification modes, but it is an important one. Its major rule is that one be consistent and precise with the attribute used to order the objects.

A Serial Ordering Activity*

You will find below a set of six different insects. You are to identify *three* different attributes by which these insects can be serially ordered. List these characteristics in the chart on the following page. Then identify an order (sequence) for all the objects in the set for each characteristic. Place the letter identifying each organism in the appropriate order in the column labeled "Serial Order." Finally, indicate the direction of that order (e.g., the smallest to largest).

Insect Specimens



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* Adapted from an exercise developed by Dr. J. Ronald Gardella, Northern Kentucky University, Highland Heights, Kentucky.

Identified Attribute	Serial Order	Order Direction

A Summary

Whether one is creating a multistage system, a binary scheme or a serially ordered system, one is still classifying. Each type of classification mode has an appropriate place in science depending upon the classification need. Lastly, each of these classification types has application in everyday life activities including non-scientific occupations.

Inferring Process Model

A few years ago, a fireworks manufacturing plant blew up and burned in northeastern Illinois. This phenomenon produced some interesting inferences. One woman who lived near Chicago and *heard* the explosion later told newsmen that she was hearing a sonic boom at the time of the explosion. A well known Chicago TV weatherman observed, from a distance, the huge cloud that formed above the factory. He admitted on TV that he had *inferred* that the cloud was of meteorological origin and had failed to figure out how this one cloud had developed on such a clear day.

Such is the state of affairs with inferences. An *inference is an explanation of an observation*. How an observation will be interpreted (or explained) is based largely upon a person's background of experiences and the logic used in the interpretation. Both the housewife and the weatherman made inferences about the fireworks factory explosion based on their observations, which were influenced by their own background of experiences—their individual frames of reference.

The weatherman was all too "human" in that he did not follow a basic rule of scientific inferring. He should have drawn *as many logical inferences* as possible that fit his observation. If he had done this, he could have had two or more inferences from which to choose. He might have concluded, after all, that the "cloud" could be more logically explained on the basis of a fire/explosion than on weather conditions (particularly on a day when there wasn't a cloud in the sky).

The intellectual process of inferring can be a fundamental tool of the scientist. It is used—and has been used historically—to assist the observer in producing new information. There are some classic cases where inferring has had great pay off value. Think for a moment where we might be today medically if Alexander Fleming had not inferred that the *Penicillium mold* he observed growing in his bacteriological plates was inhibiting the growth of bacteria. It is more than interesting to note that this same *observation* had been made before by others but that it was largely ignored. Fleming's inference led to a testable hypothesis which, in turn, led to the isolation of penicillin in the 1930s.

It is critically important to differentiate between an *observation* and an *inference*. A scientific observation is empirical data brought into the mind through one or more of the senses. The observation is available to anyone in the right place at the right time with his/her perceptive faculties turned on. The inference, however, is much more private—it is an intellectual explanation of the observation.

You walk out of the theater one summer night and the streets are wet. This you *observe*. Your *inference*? Of course, it rained! Which is hard data? Which is intellectual speculation?

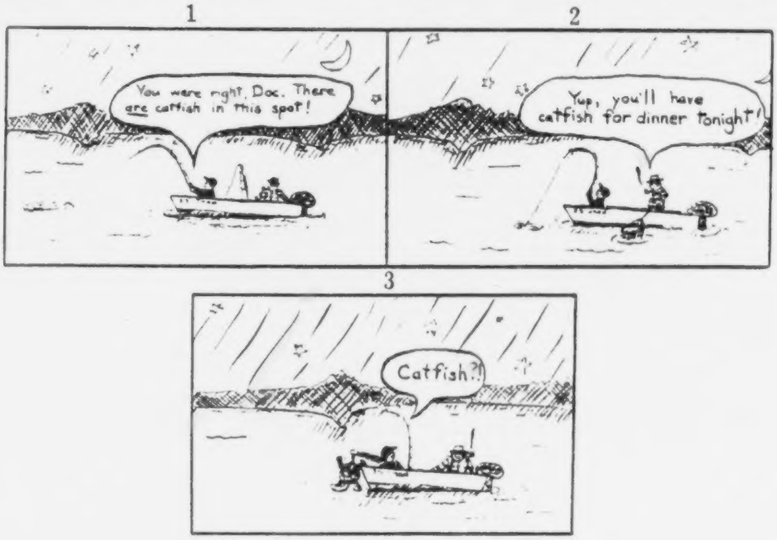
It is also critically important to distinguish between an *observation*, an *inference*, and a *prediction*. A *prediction* is a forecast or a logical predetermination of events that have yet to occur. Scientific predictions are based on data which have been observed. They are extensions of these data. This makes scientific prediction different from forecasts made by fortunetellers or soothsayers.

Prediction, then, is highly related to the skill of observation. It is also closely allied to inferring in that predictions may also be based on inferences about the relationships between *observed* events, even though the inference is an explanation of the observation. For example, the TV weatherman referred to earlier might have erroneously informed his audience that it was going to rain, based on his observation of the huge cloud and his inference that it was meteorological in origin, as well as his previous knowledge that certain clouds are associated with rainfall.

You will have further experience with the skill of prediction. For the moment, however, the important thing for you to be able to do is to separate observations from inferences and predictions. The following activity should help you learn to do this.

Observation? Inference? Prediction?

You will find below a three frame cartoon. Observe the frames closely, and read the statements associated with each frame. Then respond to the questions posed below the cartoon.


1
You were right, Doc. There are catfish in this spot!
2
Yup, you'll have catfish for dinner tonight!
3
Catfish?!

FRAME 1

1. Is the statement an observation, inference or prediction? ____________

2. Defense for your choice: ____________

____________.

3. What is the basis for the character's statement? ____________

____________.

FRAME 2

1. Is the statement an observation, inference or prediction? ____________

2. Defense for your choice: ____________

____________.

FRAME 3

1. Is the statement (question) an observation, inference or prediction? __________

2. Defense for your choice: ____

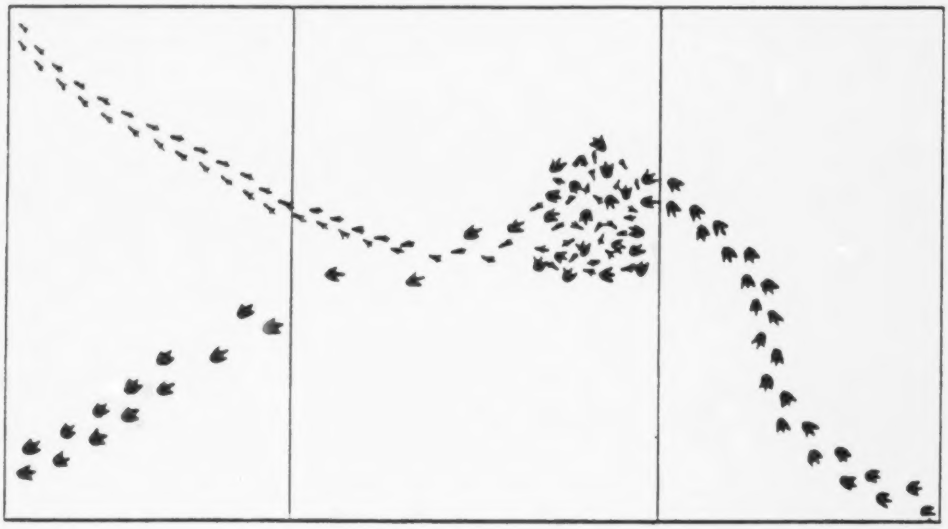
____.

In the situation depicted in the cartoon, two experienced fishermen adamantly stated one inference and one prediction. Both of these statements turned out to be incorrect. Which, if either, of the fishermen violated any of the basic premises of science in generating the inference and/or the prediction? Why?

Creating Inferences From Observations

Below, you will find a line drawing of *fossil tracks* found in a layer of *sandstone* in one of the western states. The line drawing has been separated into three parts - 1, 2 and 3. Your task is to make *observations* and *inferences* for each part.

Numerous observations and inferences can be made. A table for your lists is found on the following page along with an example. Make sure you separate your observations and inferences and that your inferences are logical ones from the data available to you. You do NOT need to use all spaces in the chart (or, you can add others if necessary).



Position 1 Position 2 Position 3

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Fossil Tracks

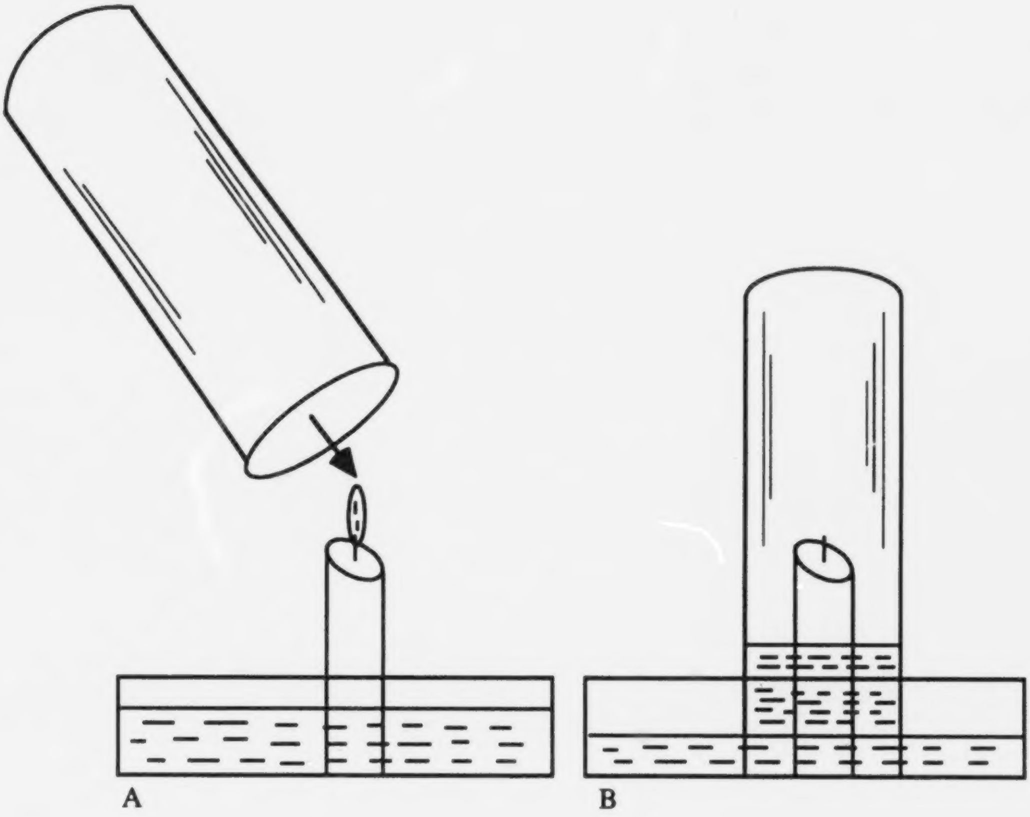
Observations	*Inferences*
Position 1 1. Example: Two sizes of footprints can be observed in the rock. 2. 3. 4.	Example: The footprints were made by two different animal species.
Position 2 1. 2. 3. 4.	
Position 3 1. 2. 3.	

Another Inferring Experience

Below are two line drawings. Part A represents a demonstration in progress. A glass bowl has a burning candle attached to its center. About half of the bowl is filled with water. A glass (or plastic) cylinder is about to be inverted over the candle into the water. The cylinder is closed at one end.

Part B represents the completed demonstration. The candle is no longer burning. The cylinder is about 20% filled with water. The water level has also gone down in the bowl.

The line drawing represents recorded data (observation). And the inference? Just what could one infer from the observed phenomena? We think it only fair to permit you to repeat this demonstration, make critical observations, and then make inferences of your own.



Necessary materials will be provided so that you can repeat this demonstration. Please make *careful observations* throughout the *entire* process. List all discrete observations below:

Necessary materials will be provided so that you can repeat this demonstration. Please make *careful observations* throughout the *entire* process. List all discrete observations below:

On the basis of your observations, is the inference "that the water level has risen inside the cylinder because the oxygen (O_2) was used up during combustion" logical? Are there other more plausible inferences? Space has been provided below for your inference(s). If there is more than one, asterisk the one that seems best.

Can you think of any way to *test* your preferred inference? How would you go about it? We are not going to ask you to test your inference but, if you did choose to test the inference, it would become a *hypothesis*. Why? Because a hypothesis is a testable generalization based on observations and/or inferences about observations. More on this later!

Inferring: The Importance of Having Information

This exercise will not only help demonstrate the process dimension of inferring, it will show the value of data available to the observer (i.e., knowledge held by the observer influences the quality of inferring). We ask that you give this activity your "intellectual all."

On the facing page you will notice a photo. Study the scene carefully. More information is providing on the following page. Feel free to read that information and turn back to the photo if you wish.

BEST COPY AVAILABLE

This photo was taken in August, high in the San Juan Mountains of southern Colorado. The observer is looking into a huge rock-lined amphitheater. Snow still remains on the slopes of the mountain. Huge deposits of soil and rock lie piled up at the foot of the rock walls which form the amphitheater. Immense, angular rocks lie scattered around within the amphitheater. Grass and alpine wild flowers cover the ground. If you look closely near the center of the photograph you can see a man sitting with his back to the photographer. He is seated on one of the smaller rocks found here.

Your task? Prepare an inference to account for the presence of the huge, angular rocks seen scattered about within the amphitheater. Write your inference below:

Don't be too frustrated if you feel you didn't do too well coming up with a reliable inference. We wonder how well you could do with some additional information. Here is that information:

> The San Juan Mountains have experienced long periods of glaciation. About 100,000 years ago, the North American climate was much colder than today. Snow piled up in the mountains each year, and large amounts did not melt. The unmelted snow turned to ice as more snow accumulated on top of it. Over the years, thick glaciers formed, and these moved down the mountains to resculpture the landscape.
>
> High on mountain tops the glacier carved huge amphitheaters out of solid rock. These amphitheaters are called *cirques* and are known as the birthplace of valley glaciers. Cirques are visible over much of mountainous North America and Europe.

BEST COPY AVAILABLE

> Glacial ice will accumulate to depths of hundreds of feet inside a cirque. As it grows in depth it also moves slowly out of the cirque and down the mountain slopes. Valley glaciers are thus formed.

Your task? Prepare a new and better inference using the new knowledge now at your disposal. Write this inference below:

Could you use still more information in accounting for the huge, angular rocks seen scattered about within the cirque? Maybe your inference would be even better given additional information. Here it is:

> As ice forms at the rear of a cirque, some of it becomes frozen to rock fragments on the wall of the cirque. As the glacier moves slowly out of the cirque, the ice may actually "pluck" these rock fragments out of the side of the mountain and carry them along.
>
> Rock fragments that have been moved long distances usually have a rounded appearance. Those that have traveled short distances usually have an angular appearance. As the years passed in the San Juan Mountains, the climate warmed. Eventually, the glaciers melted and disappeared from this mountain range.

Your task? Prepare your final inference using your observations of the photo and all accumulated knowledge. You should find this stage of inferring to be fairly easy. Further, you should have a high level of confidence in this, your last inference. Why?

Write this last inference below:

Do you feel more comfortable with your last inference than you did with either the first or the second? If so, why? Would it appear that a person's knowledge or concepts affect his ability to infer successfully?

In the specific problem revolving around glaciers, cirques, and angular rocks you may wonder whether it would ever be possible to test such an inference. In fact, it is very possible! How? Earth scientists attempt to interpret the past by observing present events. They travel to a point on the earth's surface where glaciation is active today and carefully observe the associated phenomena. It is a fairly simple matter to find analogies between present observations and evidence remaining from the past. Such is the case here. The earth scientist will readily tell you that understanding the present is the key to interpreting the past! This is an accepted assumption in the field of earth science.

Identifying Variables

PART I: A variable is something that can vary or change in a situation. Please identify the variables in the situations below:

Sample: The time it takes to run a kilometer depends on the amount of exercise a person gets.

Variable 1: time to run a kilometer
Variable 2: amount of exercise

Note: "time" and "exercise" would not be acceptable answers. Can you explain why?

1. The higher the temperature of water, the faster an egg cooks.

V-1: ____________________

V-2: ____________________

2. Jody conducted an experiment to see if different amounts of light affected the number of eggs laid by chickens on her family's farm.

V-1: ____________________

V-2: ____________________

3. Students who spend at least an hour studying each night get higher grades.

V-1: ____________________

V-2: ____________________

PART II: A manipulated variable (M-V) is one that is "changed" in a situation. A responding variable (R-V) is one that might change as a result of changing the manipulated variable. In the following situations, identify the manipulated and responding variables.

1. Andy added paper clips to his paper airplane and tested it after each addition to see how far it would fly.

M-V: ____________________

R-V: ____________________

2. Students of different ages where given the same puzzle to assemble, and the puzzle assembly time was measured.

M-V: ____________________

R-V: ____________________

3. Mike collected 2-inch balls made of plastic, styrofoam, rubber, wood, metal, and glass. He then measured how high each ball would bounce.

M-V: ______________________________

R-V: ______________________________

4. Erin administered a math test to all her seventh grade classmates. She then compared the scores of the girls to the scores of the boys.

M-V: ______________________________

R-V: ______________________________

PART III: Controlled Variables are those variables which might also influence the responding variable. In order to insure that changes in the responding variable are due to the manipulated variable (and not to other variables), we must somehow control or block the effect of all those other variables.

In each of the situations below, identify several variables which must be controlled.

1. Will the number of nails picked up by an electromagnet be increased if more batteries are added to the circuit?

Controlled Variables

a. ______________ b. ______________

c. ______________ d. ______________

2. Emily tested five different brands of paper towels to see which would absorb the most water.

Controlled Variables:

a. ______________ b. ______________

c. ______________ d. ______________

3. Bobbie conducted an experiment to see if different amounts of light affected the number of eggs laid by chickens on her family's farm.

Controlled Variables:

a. ______________ b. ______________

c. ______________ d. ______________

Hypothesizing Process Model

Earlier in the chapter, you learned that if you chose to *test a particular inference*, that inference would really become a *hypothesis*. Confusing? Perhaps, but the following information and activities should help clarify your thinking and help you become more comfortable with the process of hypothesizing.

Hypotheses are widely used in all facets of science (e.g., physics, chemistry, behavioral science). A ***hypothesis*** is sometimes defined as a ***testable generalization based on observations and/or inferences about observations***. These statements are subject to immediate or eventual testing by one or more experiments.

As one studies both of the above definitions, three key characteristics of hypotheses emerge. They are: (1) hypotheses are generalizations; (2) hypotheses must be testable; and (3) they are based on observations and/or inferences. Let's see how these characteristics might apply in a specific behavioral science situation.

Assume that you are a sixth grade teacher who is also interested in doing educational research. Your observations of sixth grade students seem to infer that they are, many times, motivated to learn for the sake of grades. You ponder this and decide to enlist the help of a number of fifth, sixth, and seventh grade teachers in conducting an experiment to test your inference. Your research hypothesis might read as follows:

> *Research Hypothesis*: Middle school students will perform significantly better when extrinsically motivated by grades than students who have no such external motivation for learning.

Is the above statement a generalization? If so, to whom does it generalize? Is it based on observations? Inferences? Both? Can it be tested? If so, how? On the basis of your responses to these questions, you should have determined that the sixth grade teacher's statement fits the definition of a hypothesis.

More On Hypothesizing!

When a hypothesis is stated, it tends to describe a *specific relationship* between factors (variables) in a given situation. Indeed, well stated hypotheses may be considered to be attempts to predict the effect that one variable has on another variable (e.g., if x increases, then y will increase). In the research hypothesis presented earlier, *a relationship* between one variable (school performance) and another variable (type of motivation) was stated. The teacher was attempting *to predict* that using extrinsic motivation would positively increase students' performance.

Critical to the task of formulating good hypotheses is the ability to identify the pertinent variables inherent in a particular situation. To quickly review, these variables fall into one of three types. The types are:

1. *Manipulated Variable*: the variable which is purposefully (deliberately) changed in a situation. Another name for the manipulated variable is the independent variable.

2. *Responding Variable*: the variable which may change or be affected *as the result* of the manipulation. A responding variable can also be called a *dependent variable*.

3. *Controlled Variables:* the variables which are purposefully held constant or stable in a situation, thereby allowing only one variable to be manipulated and its effects on the responding variable to be determined.

Hypothesizing involves examining a situation and identifying the variable which is to be manipulated (tested), the variable which responds to the manipulation, and the variables which will be purposely controlled. The hypothesis is then stated. It should contain both the manipulated variable and the responding variables, as well as the relationship between the two. It is not necessary to state the controlled variables in the hypothesis, although they become very important when the experiment to test the hypothesis is designed.

The activity which follows should give you some experience in identifying the kinds of variables which are stated in hypotheses.

Identifying Variables - One More Time

You will find below three hypotheses. Read them carefully and identify the manipulated variable and the responding variable within each. Lastly, describe the type of relationship which exists between each manipulated and responding variable.

Hypothesis 1:

A population density of fewer than three immature angel fish per gallon of aquarium water will result in more rapid growth of individuals in that population than will a population density of three or more fish per gallon of aquarium water.

Manipulated Variable: ______________________________

____

Responding Variable: ______________________________

____

Relationship: ______________________________

____

Hypothesis 2:

Greenhouse orchid plants fertilized every fourteen (14) days with a dilute solution of 20-20-20 will produce more flowers than those fertilized only once a month.

Manipulated Variable: ______________________________

____

Responding Variable: ____

____

Relationship: ____

____

In the above activity, the hypotheses had already been written. A more difficult task is to construct a hypothesis for a particular situation. Let's try that next.

Constructing Hypotheses

Assume that you are a naturalist who is studying bumble bee reproduction. You observe that varying numbers of young bees hatch from the three equal sized underground nests you are studying. You wonder what factors might influence the hatching rate of the bumble bees. You infer that one factor might be the temperature in the nest and that another possible factor might be the number of adult bumble bees available to tend the developing larvae. Construct two hypotheses—one for each of the inferences stated above.

1. Hypothesis: ____

____

____

2. Hypothesis: ____

____

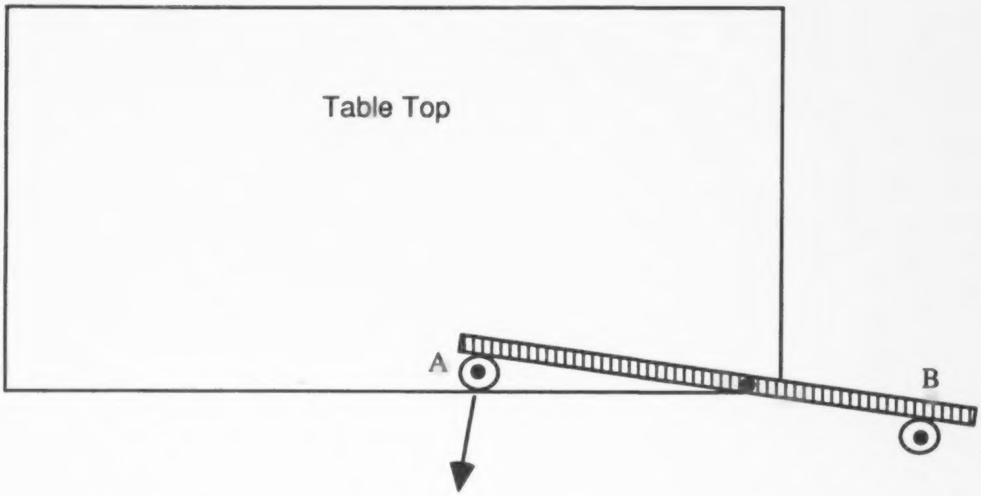
____

Do you really know what the effect of manipulating each of the above variables will be? Not really—that is, not until you design a set of experiments which test the hypotheses you constructed.

Now we are going to put you into the real three dimensional world of hypothesizing. Follow instructions carefully!

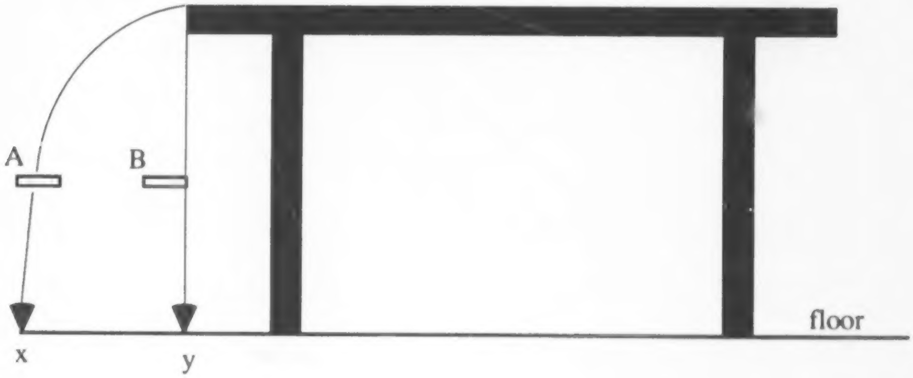
Hypothesizing In Earnest!

For this activity you will need one 30.5 cm ruler (center punched), two coins of equal denomination, an assortment of other coins, paper or cardboard and a pencil. In this activity you are going to observe the effect of gravity on falling bodies (e.g., coins). Before you can do this effectively, however, you must develop some psychomotor (manual) skills.



Using a table top, ruler, and two coins of equal denomination (e.g., 2 nickels, 2 quarters, 2 dimes) set up the demonstration as you see it in the drawing above. Place the pencil in the center punched hole so that it acts as a pivot point.

Using your middle finger, flick the ruler in such a way as to force coin A off the table and coin B off its station on the rule. This can be difficult to accomplish at first so practice until you have the technique down pat. When you have polished your technique, the results you obtain will appear to be something like the following:



Now, record your observations of the phenomenon as it relates to the "behavior" of the two coins.

Observations:

Now, try the same procedure with two identical coins of a *different denomination*. For example, you might use two half dollars. Carefully observe what happens.

Does a hypothesis come to mind? One should! It should relate to a generalization concerning the phenomena you have observed. Write this hypothesis below:

Hypothesis 1:

The following represents one possible hypothesis for the above events: *Objects of equal mass, whether dropped or pushed from equal heights, will hit the floor at the same time.*

Is the hypothesis testable? How would you go about testing it? Think of specific ways of testing your hypothesis.

Now let's modify the situation slightly. Repeat the demonstration using coins of two very different masses (e.g., a quarter and a dime). What do you observe the results to be? Repeat the procedure a second—even a third or fourth time using different coin combinations. Was the original hypothesis a good one? Did it account for enough variables? If not, revise the original hypothesis below:

Hypothesis 2:

Is Hypothesis 2 testable? Does it follow the rules for hypothesizing? Think of specific ways of testing this hypothesis. You might, for example, want to use entirely different objects this time. In fact, test the hypothesis by using a coin and a small, flat piece of paper provided by your instructor.

The data from the above test for Hypothesis 2 should eventually lead you to revise Hypothesis 2. If your inferences are based on all possible data, and if you have used good logic in forming your inference(s), you win be forced to write a third hypothesis that could be tested (but only in a more sophisticated laboratory than the one in which you are working). How would that hypothesis read?

Hypothesis 3:

It should be obvious, at this point, that hypotheses are, in fact, very special kinds of inferences about the universe. Further, they must be testable, and they should relate to some generalizable principle or concept. Even though a research hypothesis may not prove itself to be correct, it still functions as a focal point of research in that it establishes the guidelines for experimentation. The hypothesis is accepted, rejected, or revised on the basis of the experimental results.

Paper Plane Hypothesizing

For this activity you will need one 30.5 cm. ruler, one paper airplane with attached rubber band, and the data collection sheet in your worktext. (See the following page for directions for making a paper airplane).

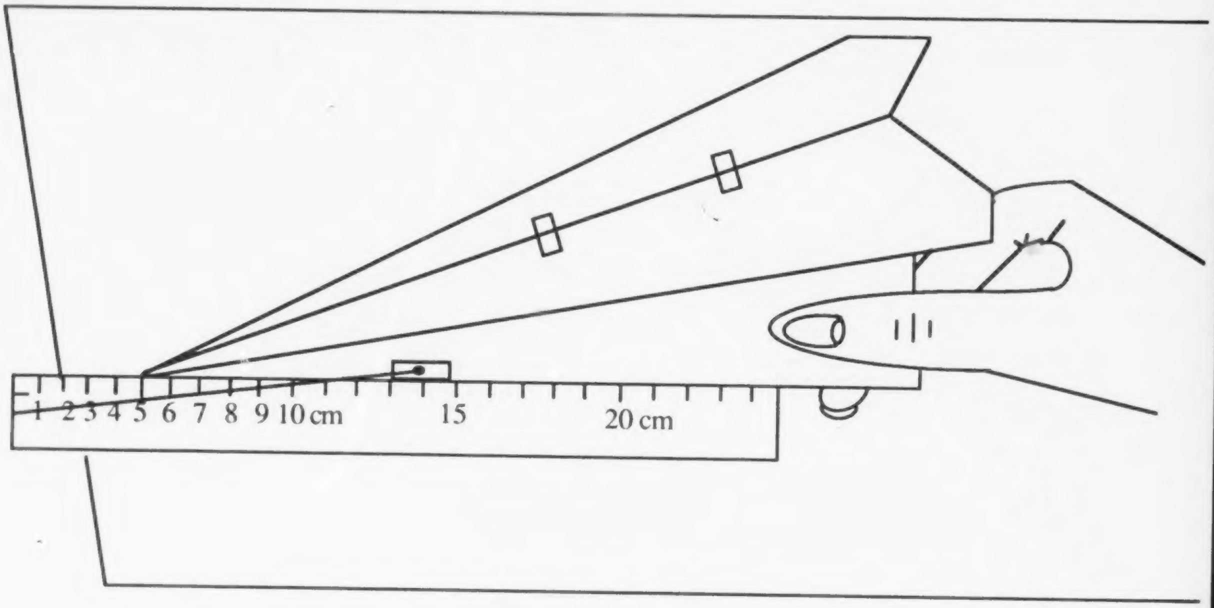
What do you think will happen to the length of the flight of a paper airplane when it is launched with increasing amounts of energy? Write your hypothesis in the space below.

Hypothesis: ______________________________

____

____

Launching a Paper Airplane



To launch a paper airplane place a ruler lengthwise and flush with the surface of a table, desk, chair or similar horizontal surface. Loop the rubber band attached to the plane over the end of the ruler as close to the top of the ruler as possible. Grasp the tail of the plane with the thumb and forefinger. Pull the plane backward, stretching the rubber band. Measure the amount of launching energy by the number on the ruler at which the plane's nose rests. To launch the plane, quickly release the grip you have on the plane's tail.

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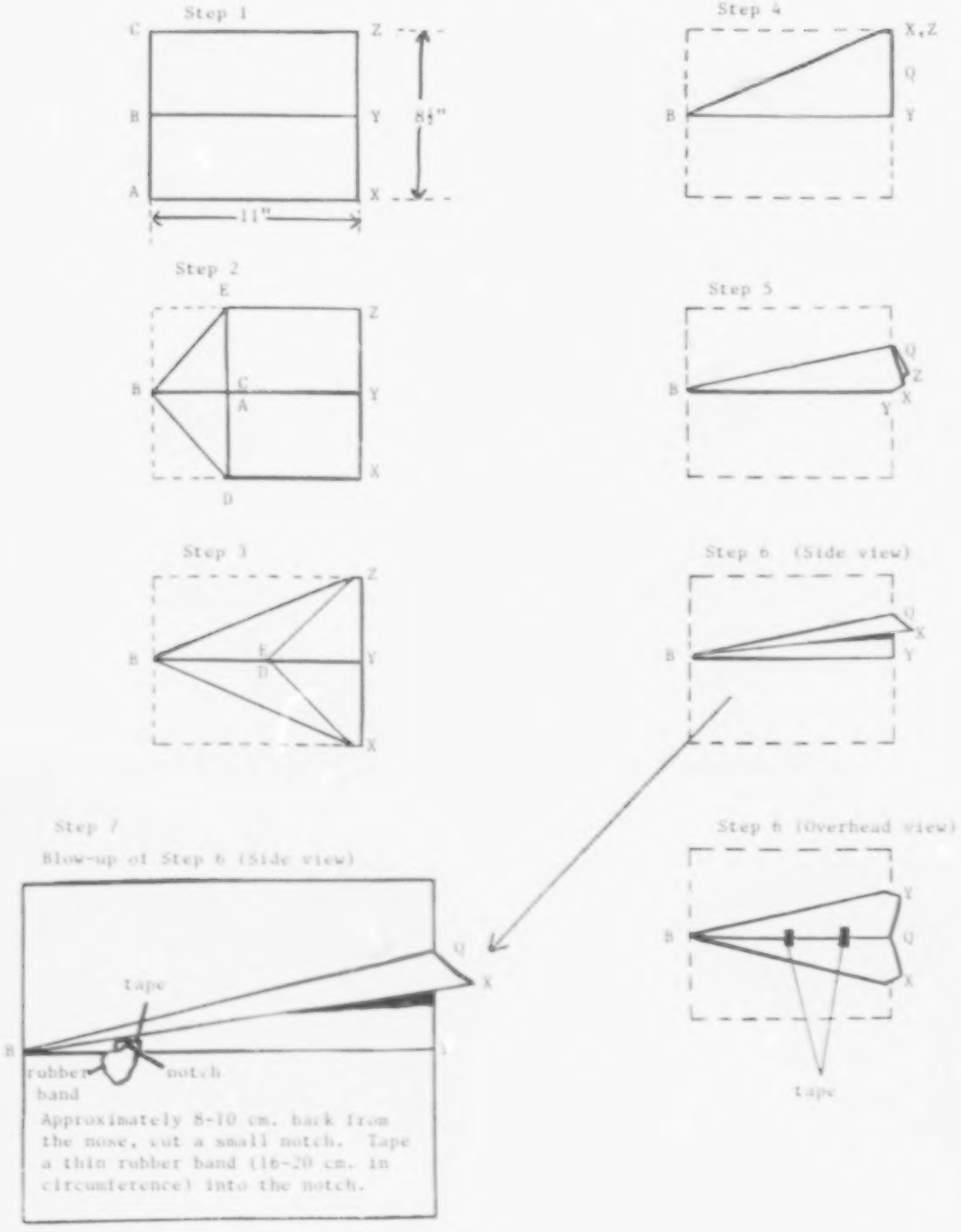
Steps in Making A Paper Airplane


Step 1
C
Z
B
Y
8½"
A
X
11"
Step 2
E
Z
B
C
A
Y
X
D
Step 3
Z
B
E
D
Y
X
Step 4
X,Z
Q
B
Y
Step 5
Q
Z
B
X
Y
Step 6 (Side view)
Q
X
B
Y
Step 7
Blow-up of Step 6 (Side view)
tape
Q
X
B
A
rubber band
notch
Step 6 (Overhead view)
Y
B
Q
X
tape

Approximately 8-10 cm. back from the nose, cut a small notch. Tape a thin rubber band (16-20 cm. in circumference) into the notch.

Controlled Variables

Before you begin to collect your data, you will need to identify variables that will have to be controlled. Make a list below.

____

____

____

Data Collection

In groups of 2-4 gather your data on the data collection sheet provided for you.

DATA COLLECTION SHEET

		DISTANCE TRAVELED		
ENERGY AS MEASURED BY # ON RULER	TRIAL 1	TRAIL 2	TRAIL 3	AVERAGE OF TRIALS 1, 2, and 3

Data Interpretation

Once you have collected your data you will need to interpret that data. Do so in the space below.

Data interpretation:

Hypothesis Decision

You are now ready to conclude this activity by making a decision regarding your hypothesis. Your decision can be to accept the validity of the hypothesis, to reject the validity of your hypothesis, or to suspend judgment regarding the hypothesis' validity.

If your data are orderly and reveal a consistent pattern, you should be able to accept or reject your hypothesis with confidence. If the pattern of the data is irregular or erratic, however, you may choose to suspend judgment and redo the experiment, making an attempt to exert better control over any variables which you think may be affecting your data.

Please make your hypothesis decision below. Check one.

Hypothesis decision: _______ Accept
_______ Reject
_______ Suspend judgment

Interpreting Sunspot Data

On the next pages you will find graphs which portray biennial sunspot numbers (data) between 1800 and 1990. Sunspot data, like so many other data, help generate the scientific assumption that the happenings in the universe are mostly governed by laws, and that events are not capricious and unpredictable (i.e., scientists believe that there is order in the universe).

Interpreting data involves observing known information with the expectation of determining what those data indicate. Put another way, when we interpret data, we try to answer the question, "What do the data mean (i.e., what do they tell us about events under investigation)?"

If you observe the sunspot data carefully, you should be able to see some patterns or repeated phenomena that indicate a certain orderliness in those data. If this is the case, you should be able to state a generalization (data interpretation) concerning sunspot activity between 1800 and 1990. This generalization could consist of one sentence or several. Try your hand at interpreting these sunspot data.

My interpretation of sunspot data:

How would you go about checking the *validity* of your interpretation? A number of questions should help determine the validity of your generalization. Is your interpretation totally consistent with the data? Have you overgeneralized (i.e., have you written some statements that are really not supported by the data)? Do others agree that your generalization is correct? It might be wise to check your interpretation against those prepared by others looking at the same data.

Predicting Future Sunspot Activity

Scientists also use data interpretation techniques to *predict* future events. Who in the world would be interested in *predicting* future sunspot activity? Lots of people! Why? There is, for example, a high correlation (relationship) between the degree of sunspot activity and radio reception. Two-way radio and home satellite dish reception can be adversely affected during periods of high sunspot activity. There is also some evidence that certain animal population cycles are correlated with sunspot activity. This information would be of considerable importance to wildlife managers. Also, tree growth has been shown to be correlated (historically) with sunspot activity. Who might be interested in those data? Thus, sunspots can be of vital concern to particular elements of society and the scientific/technological community.

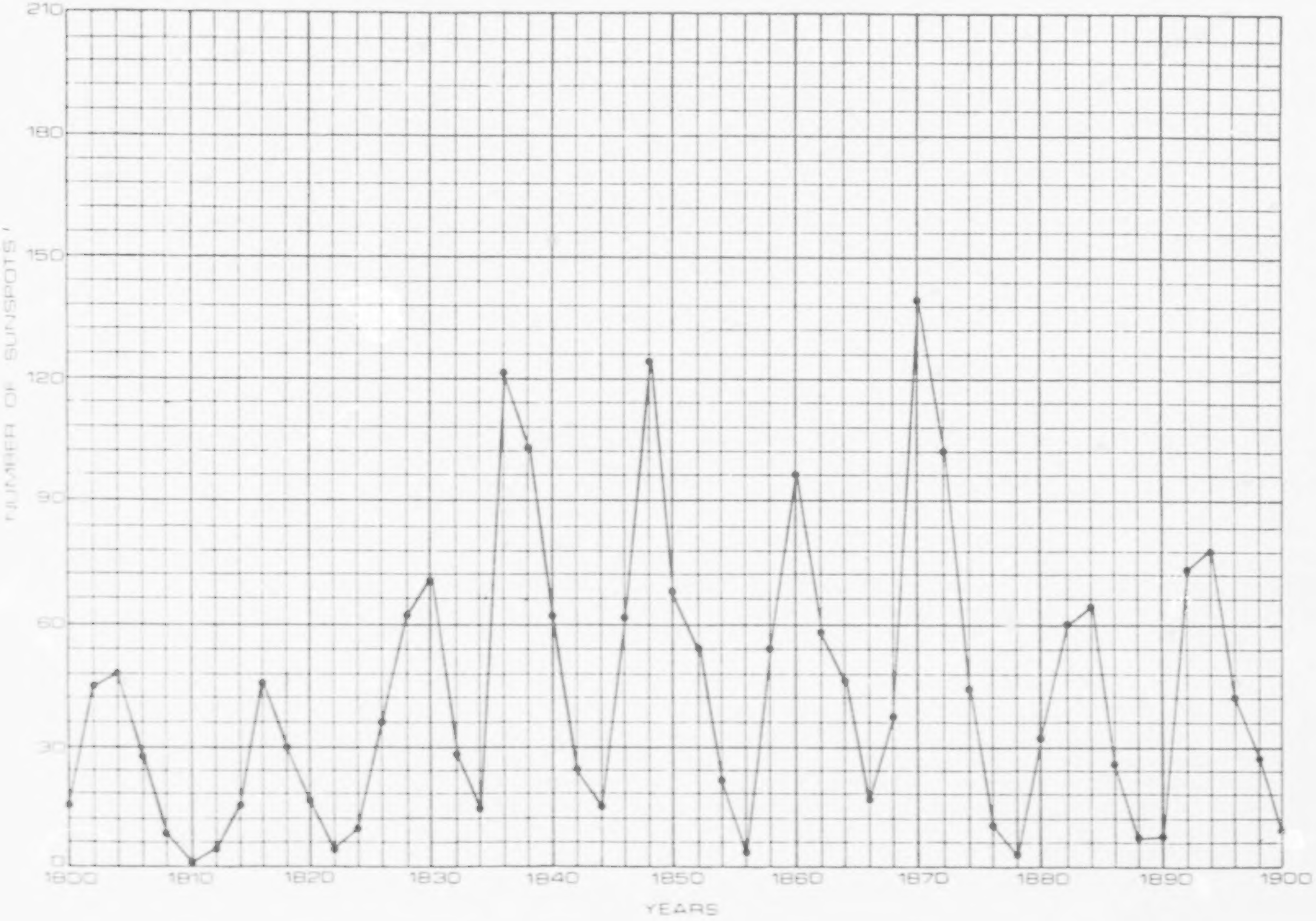
Do you think that there are enough data in the accompanying graphs to predict future sunspot activity? If so, how accurately do you think you could do this?

Let us assume that it is crucial for you to be able to predict a pattern for sunspot activity between 1990 and 2030. What would your best scientific predictions be? Write those out below. Also, please provide an explanation for your predictions.

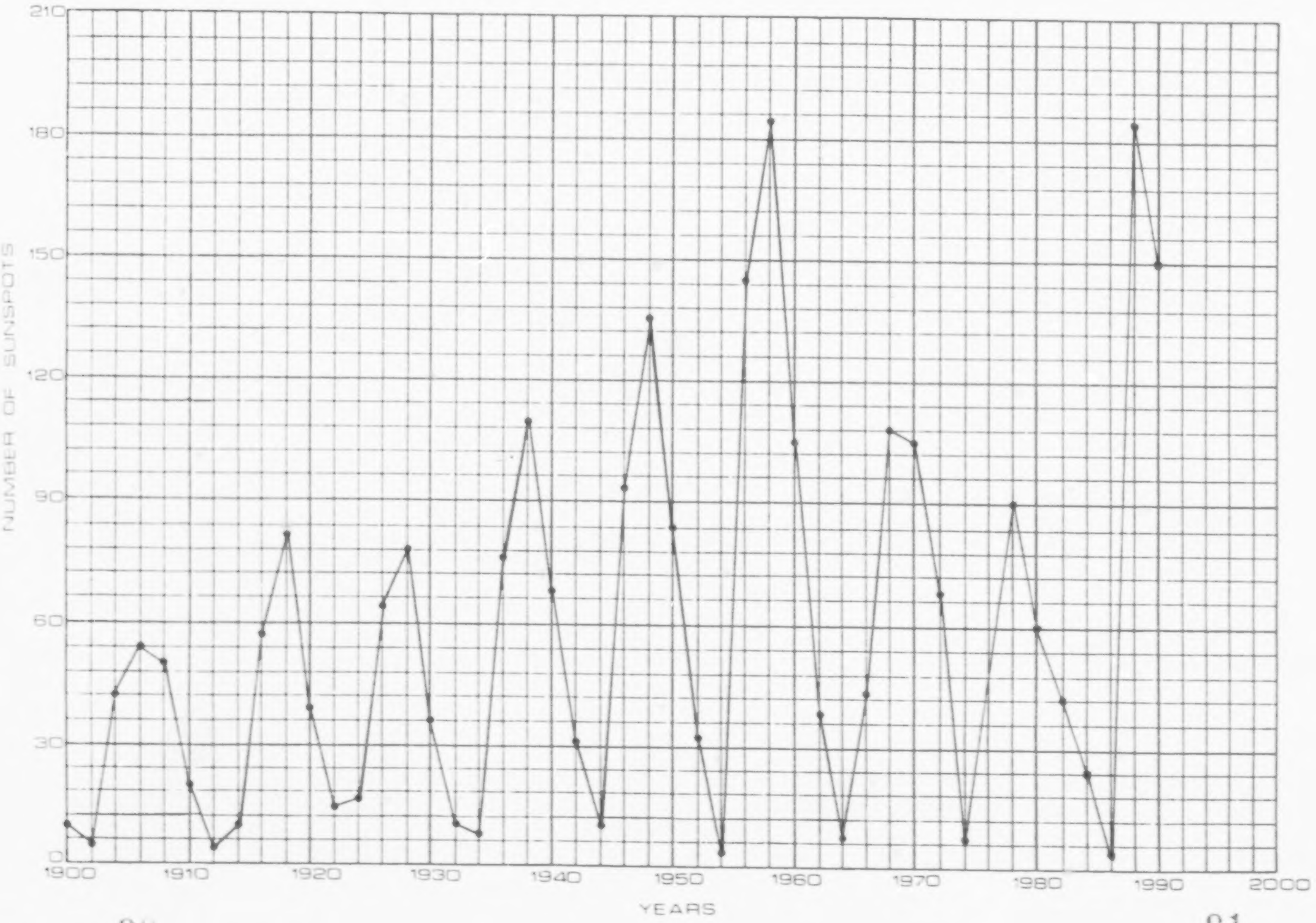
My predictions:

My explanation:

BIENNIAL SUNSPOT NUMBERS, 1800 - 1900



BIENNIAL SUNSPOT NUMBERS, 1900-2000



Graphing - One Form of Scientific Communication

Preparing and interpreting graphs are two very important skills used in the science classroom. Accurate and clear data communication is crucial in science. Graphs are valuable in that they often present data to the viewer in a more readily understood form than a tabular or written presentation.

Rules for Graphing

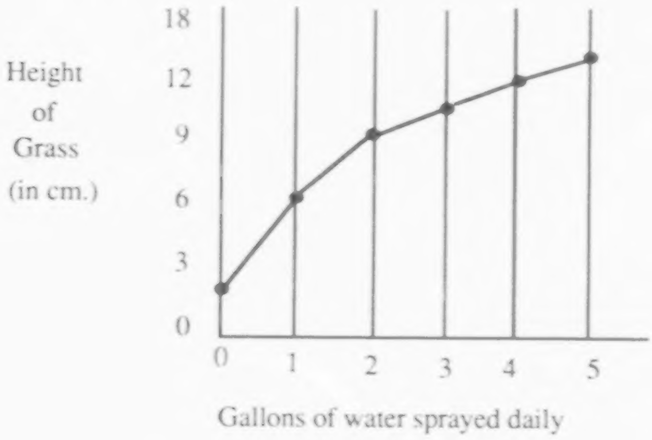
The Coordinate or Line Graph: The coordinate/line graph is typically used to show increases and/or decreases in variables or to show change in variables over time. Here we are involved with data which can be displayed in a continuous line or set of lines.

Rules for constructing a coordinate/line graph include:

1. The graph should have a title that succinctly but adequately describes the relationship between the graphed variables.
2. The systematically changing variable (in experimental data this is the independent/manipulated variable) is presented on the horizontal axis.
3. The data which represents the observed results (in an experimental setting this is the dependent/responding variable data) should be presented on the vertical axis.
4. Both axes should be labeled to identify which information or variable each represents.
5. All intervals on an axis should be numbered so that they are equal and continuous.
6. Coordinates or data must be plotted accurately.

The graphs depicting sunspot data on previous pages are examples of coordinate/line graphs. The graph below is also a coordinate graph.

HEIGHT OF GRASS IN SIX DIFFERENT PLOTS AFTER 10 DAYS OF BEING SPRAYED DAILY WITH DIFFERENT AMOUNTS OF WATER

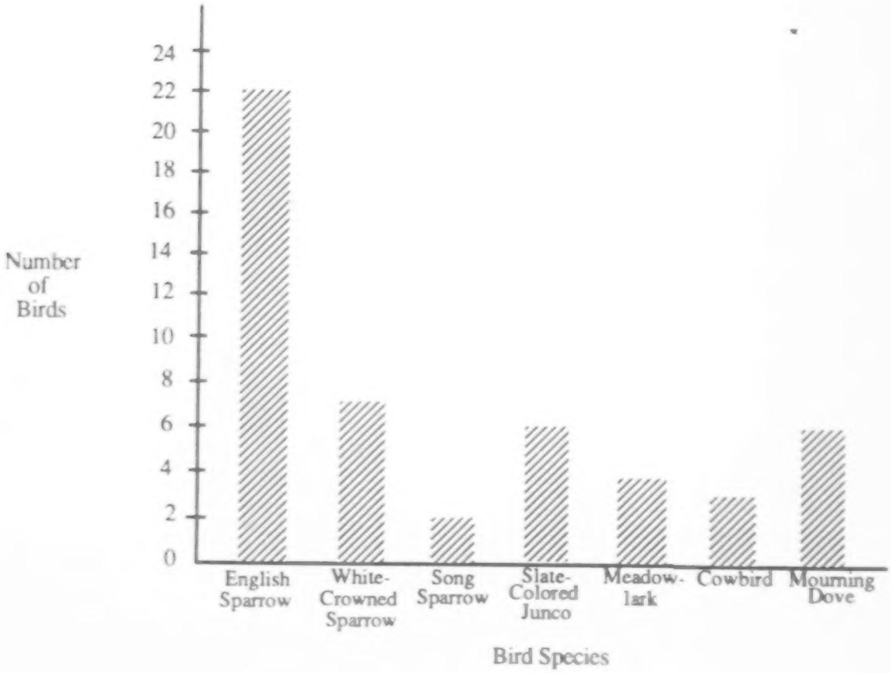


The Bar Graph: If the need is to graph numerical data related to categories (categories such as different school subjects or types of music), then a bar graph is used. (See example below.)

Rules for constructing a bar graph include:

1. The graph should have a succinct title, describing what the graphed data is presenting.
2. The specific categories are presented on the horizontal axis (also called the x axis) with equal sized spaces left between the categories.
3. Numerical intervals identified on the vertical axis (also called the y axis) should be equal and continuous.
4. Both axes should be labeled to indicate what information each represents.
5. The actual data must be plotted accurately.

NUMBER OF BIRDS, BY SPECIES, OBSERVED AT THE JOHNSON'S FEEDING STATION AT 8 AM ON JANUARY 21, 1984



Recording and Interpreting Ecological Data

It is much easier to report and interpret data in science when it is reported in an orderly, organized manner. Similarly, many situations appear to demand the use of graphically presented information. Regardless of the mode used, accurate and clear communication of data in science is critically important.

A demonstration of the need for clear, concise communication seems in order. We will use historical ecological data for this purpose.

Significant fluctuations in the deer population occurred on Arizona's Kaibab Plateau between 1905 and 1938. These population figures represent one of the classic case studies in North American wildlife management. In 1907 there were approximately 6,000 deer on the plateau. By 1910, they had increased in number to 10,000, and by 1915, the population had risen to 25,000. The year 1920 saw approximately 56,000 deer present, and by 1923, the population had soared to 100,000. 1925 saw the population decrease to 85,000, and by 1930, it had fallen to 30,000. In 1935, there were but 14,000 deer present, and in 1938, the population had been reduced to 9,000 animals.

Now let's present these same data in a different format. They follow:

Deer Population on the Kaibab Plateau from 1907 to 1938

Year	Approx. Population of Deer
1907	6,000
1910	10,000
1915	25,000
1920	56,000
1923	100,000
1925	85,000
1930	30,000
1935	14,000
1938	9,000

If you had to comprehend and interpret the Kaibab deer population figures, which of the above two presentations would you prefer using? Certainly, it is obvious that the tabular presentation far surpasses the written paragraph presentation. However, is there still a better way—or, an equally effective means of communicating these data?

We are going to ask you to graph these same data using the graph paper found on the following page. A coordinate graph would probably be the most efficient. Please do this graph at this point in time.

You now have available three separate models of the Kaibab deer population data. Which would you prefer to use for interpreting data?

In keeping with the intent of this activity, we are going to ask you to use these data for the application of several science process skills. First, what *conclusion* can you produce from the deer population data? In science, the *conclusion* is a term that is often abused. A *conclusion* is a statement which summarizes a set of observations made regarding some particular phenomenon. It is *not* an inference (i.e., an explanation). With this definition in mind, produce a defensible conclusion from the data. The conclusion should adequately reflect all the data.

Conclusion:

What logical, scientific *inference* can be stated concerning these data? If you recall that an inference is an expression of an explanation of an observation, you will quickly realize that any inference stated about the data at this point would, by necessity, have to be quite vague and largely meaningless. Once again, this points up the need for knowledge in conducting the business of science.

With additional information, you should be able to *infer* at a high level of competence. Let's see how well you can infer with more information given.

Between 1907 and 1923, 300 coyotes and 600 mountain lions were killed on the Kaibab Plateau. For the years between 1907 and 1923, write the best possible inference you can from all the data available.

Inference:

More information might make your Kaibab inference even more powerful. Once again, we will provide additional information. As the deer herd began to increase, the range of the deer began to be overgrazed. During the years of decreasing deer populations, the range of the deer was so badly overgrazed that thousands upon thousands of deer died from starvation. What logical inference can you now pose based on all available data (1907-1938)?

My Best Inference:

The "All Purpose" Process Model

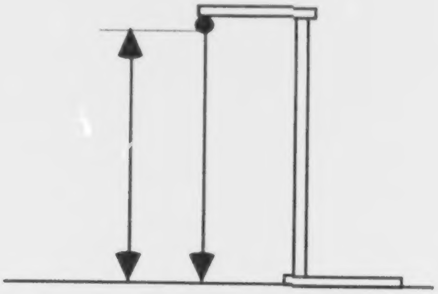
This process model incorporates many of the processes in which you have already received training. These processes include observation, comparison, hypothesizing, controlling variables, data collection, graphing, data interpretation, and experimentation.

Hopefully, upon completion of this model, you will understand how many science processes or critical thinking skills can be used in combination during a problem-solving situation. Also, you should begin to see that processes are used in a certain *sequence* when scientific problem-solving (i.e., experimentation) takes place. Finally, it is hoped that the relationship between process and product in science will be better understood.

In this model, you will work with the pendulum. To make a pendulum system you will need some sort of support structure (one will probably be provided). From this support structure, a string is suspended. At the bottom of the string you will need to affix some sort of weight holder like a shower curtain hook which will hold metal washers or a paper cup which can hold sand or marbles. The figures that follow in this model should help you perceive how a pendulum is set up.

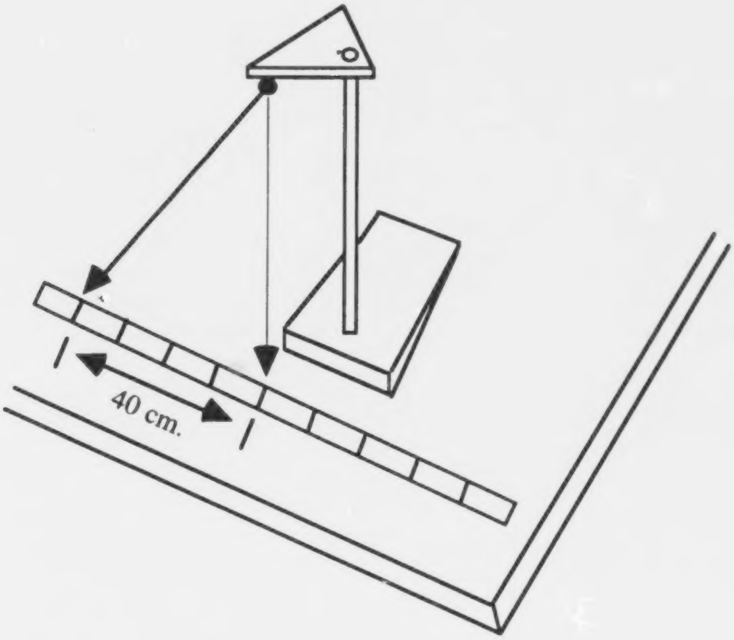
Some of the variables or factors operating in this process model with which you need to become familiar are:

1. The *length* of the pendulum is the distance from the place the string is affixed to the structure to the bottom of the weight holder. See diagram below:

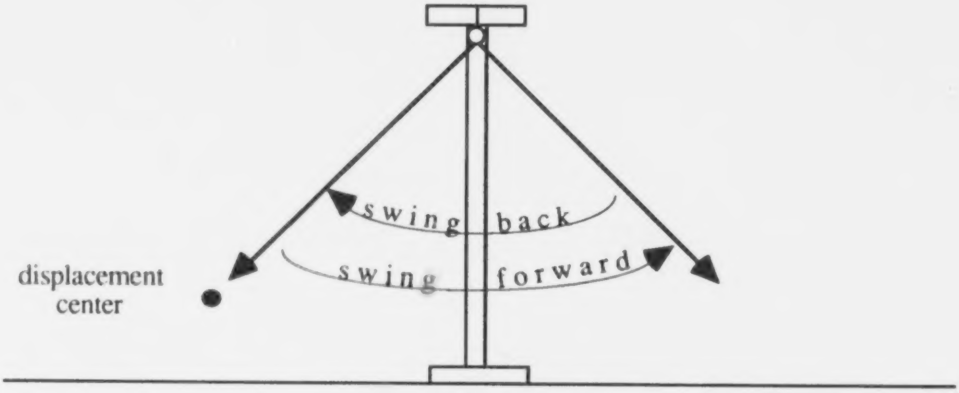


2. *Weight* in the pendulum system can be measured by: (1) the actual weight of the objects suspended in the system (i.e., the actual weight of the sand, the marbles, or the washers), or, (2) the total number of objects being suspended in the system (i.e., 2 marbles = 2 marble units; 5 washers = 5 washer units).

3. *Displacement* in the pendulum system is the distance the pendulum is moved from its stationary position. In the diagram below, the displacement is equal to 40 cm.



4. *Vibration* in the pendulum system is a complete swing forward and back from the point at which the pendulum was displaced. Please refer to the following diagram.



one vibration

5. *Frequency* is the number of vibrations that take place within a specified time span. For example, if the time span specified is 30 seconds, and the pendulum has 10 vibrations in 30 seconds, the frequency is 10 vibrations in 30 seconds.

The behavior of a pendulum might seem to be affected by several variables. In the activities that follow, you will have an opportunity to discover a set of relationships regarding certain variables and pendulum behavior. You might also be stimulated to seek answers because things did not turn out the way you expected them to (i.e., the outcomes were discrepant). Discrepant events many times excite the curiosity of scientists and are the phenomena *which initiate scientific problem-solving*. Let's see if pendulums display any discrepancies. Let's investigate!

Experimental Activity 1 -

What do you think will happen to a pendulum's *frequency* if the weight in the pendulum system is *increased*?

In the space provided below, form a hypothesis that will describe what you think will happen. Remember to apply the rules for hypothesizing that you have learned.

Hypothesis: ____

____

____

The validity of a hypothesis is determined by the results of experimental tests which scientists design and conduct. Your task is to design and conduct such an experiment to test the hypothesis written above. Systematic analysis of your hypothesis should help you design a good experiment.

As you examine the hypothesis you constructed, identify which variable will be manipulated. Weight? Right. Remember that in an experiment the manipulated variable (the variable over which the experimenter has control) is called the *independent variable*.

Identify the variable in the hypothesis that would respond to the weight manipulation. Frequency? Yes! As you will recall, in an experiment, the variable that responds to the manipulated variable is called the responding or *dependent variable*.

In the experiment you design to test the relationship between increasing weight and pendulum frequency, what displacement and length will you use? Should you hold these variables constant (i.e., should you use the same displacement and the same length in each of the trials)? Yes, for if you do not hold length and displacement constant (control the variables), you will need to redo the experiment. Why? Because if you were to change the variables of weight, displacement, and length at the same time, you would be unable to determine which variable the frequency responded to—change in weight ?, change in displacement ?, or change in length ?. In an experiment, only one variable should be manipulated at a time. All other variables except the responding variable should be *held constant* or *controlled*.

Conduct the experiment you have designed to test the hypothesis you wrote. Record the data you collect in the table which follows.

Weight-Frequency Experiment Data

Trial	Weight	Displacement	Length	Frequency (30 Sec.)
1				
2				
3				
4				
5				
6				
7				
8				

Now, interpret your collected data in the space below:

Do the data support or refute your hypothesis? Mark your decision below:

Hypothesis decision: _________ Accept _________Reject

_________ Suspend Judgment and Redo Experiment

Why? ______________________________

____

If you rejected your hypothesis, how would you restate it on the basis of the data you collected?

Hypothesis: ______________________________

____

____

Experimental Activity 2 -

Hypothesize what you think will happen to the frequency when *displacement is increased* in a pendulum system.

Write your hypothesis below.

Hypothesis: ____

____

____

Design and conduct an experiment to test this hypothesis. Answer the following:

Which variable is the manipulated or independent variable? ____________

____

Which variable is the responding or dependent variable? ____________

____

Which variables are controlled? ______________________________

____

Record the data you collect in the following table.

Displacement-Frequency Test Data

Trial	Weight	Displacement	Length	Frequency (30 Sec.)
1				
2				
3				
4				
5				
6				
7				
8				

Data Interpretation:

Hypothesis decision: ________ Accept ________Reject

________ Suspend Judgment and Redo Experiment

If you rejected your hypothesis, how would you restate it on the basis of the data you collected?

Hypothesis: ____

____

____

Experimental Activity 3 -

Hypothesize what you think will happen to the frequency when length is increased in a pendulum system.

Write your hypothesis below.

Hypothesis: ____

____

____

Design and conduct an experiment to test this hypothesis. Answer the following:

Which variable is the manipulated or independent variable? ____________________

____

Which variable is the responding or dependent variable? ____________________

____

Which variables are controlled? ______________________________

____

Record the data you collect in the following table.

Length-Frequency Test Data

Trial	Weight	Displacement	Length	Frequency (30 Sec.)
1				
2				
3				
4				
5				
6				
7				
8				

Data Interpretation:

Hypothesis decision: ________ Accept ________Reject

________ Suspend Judgment and Redo Experiment

If you rejected your hypothesis, how would you restate it on the basis of the data you collected?

Hypothesis: ____

____

____

Next, on the following pages of graph paper, prepare three (3) graphs which illustrate the relationships between: (1) frequency and weight, (2) frequency and displacement, and (3) frequency and length. Use the data you collected in Activities 1, 2 and 3 in preparing the graphs. In each graph, locate the *independent* variable on the *horizontal* axis and the *dependent* variable on the *vertical axis.*

Although there can be many types of relationships between variables, they usually fall into one of three major types. These are (1) direct; (2) indirect; and (3) constant relationships. In a direct relationship the independent and dependent variables change in the same way (i.e., as one increases, the other increases or vice versa). In an indirect relationship if one variable changes, the other changes in the opposite direction (i.e., if the independent variable increases, the dependent variable decreases or vice versa). In a constant relationship situation, a change in the independent variable has no effect on the dependent variable. In the pendulum activity, what type of relationships did you find between (1) frequency and weight; (2) frequency and displacement; and (3) frequency and length?

Upon the completion of the three graphs, respond to the following assignment: Interpret all graphed data. Use your data interpretation to produce a rule or principle which summarizes the influence of weight, displacement, and length in a pendulum system.

Principle:

A Sample Deductive Lesson Plan: Graphing

GRAPHING LESSON PLAN

You have now completed a variety of process models designed to teach a number of critical thinking skills from the fundamental skill of observation to the complex skill of experimentation. Critical thinking skills can be taught via both inductive and deductive means. You will be provided an example of an inductive lesson plan later in the work-text. Here you will find a lesson plan based on a deductive presentation. The critical thinking skill involved here is graphing.

LESSON PLAN FOR THE COORDINATE/LINE GRAPH

I. Objectives

Given a set of data, a sheet of graph paper, and a ruler, the student will construct a line graph. To complete the graph successfully, the student will be expected to . . .

1. ... place a title at the top of the graph that describes the relationship between the two variables represented by the data.
2. ... label the horizontal axis with the independent (manipulated) variable and the corresponding unit of measurement.
3. ... label the vertical axis with the dependent (responding) variable and the corresponding unit of measurement.
4. ... number both axes such that each interval on an axis represents the same number of units of measurement.
5. ... number both axes to the extent that all the data can be plotted.
6. ... plot the coordinate points accurately.
7. ... connect line segments to consecutively plotted points.

II. Materials Needed

For the Lesson

1. sunrise graph
2. data collection sheets
3. graph paper
4. rulers
5. candles
6. matches
7. jars of the following sizes: 1/4 pint, 1/2 pint, quart, 1/2 gallon, gallon

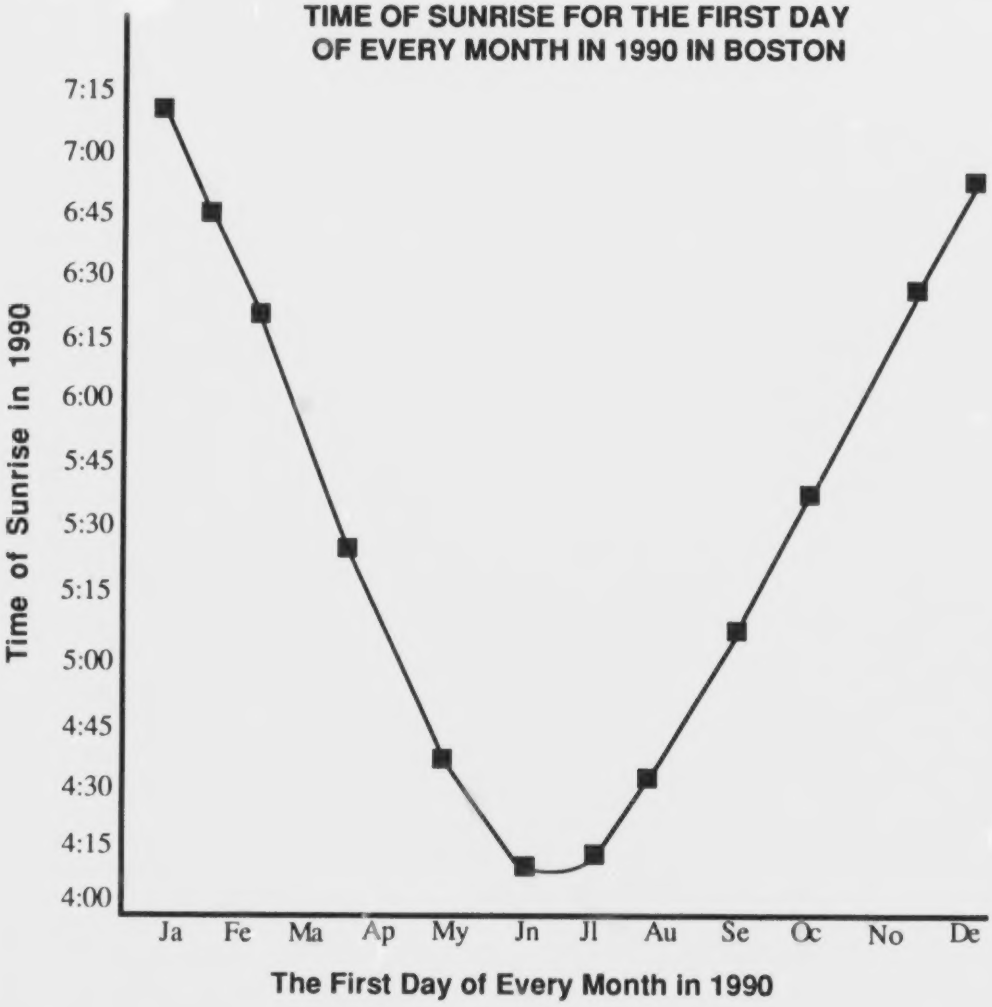
For the Evaluation

1. data sheets with data filled in
2. graph paper
3. rulers

III. Instructional Procedures

Part A:

1. Present the students with the following line graph:



2. Discuss with students the following parts of the graph: (1) title, (2) axes labels, (3) axes on which the manipulated and responding variables belong, (4) numerical intervals, (5) plotted coordinates, and (6) the line segments themselves.

Part B:

1. Demonstrate how to "sneak up" on a burning candle (i.e., quickly rather than slowly bring the jar over the burning candle).
2. Discuss when to start and when to stop timing the suffocating candle.
3. Discuss multiple "burns" per jar to get a more accurate burning time.
4. Distribute data sheets, candles, matches, and jars to each pair of students.
5. Guide students in collection of data.
6. Review with students how to set up a line graph.
7. Discuss with students the accurate completion of the graph.
8. Allow students ten (10) minutes to complete a graph of their collected data.
9. As students plot data, circulate among them to check on their progress and to make helpful suggestions if necessary.

The Data Collection Sheet

Jar Size	Jar Size (In Units)	Burning Time (In Seconds)
1/4 pint		
1/2 pint		
quart		
1/2 gallon		
gallon		

IV. Evaluation

The students will be given: (1) a set of data unrelated to that in the lesson, (2) graph paper, and (3) a ruler. The students will be instructed to accurately set up and complete a line graph of the data that follow:

WEIGHT OF ICE	MELTING TIME
2 oz.	1 min.
5 oz.	4 min.
8 oz.	9 min.
12 oz.	15 min.
17 oz.	22 min.

Construct a line coordinate graph which displays the data found in the above chart.

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Chapter Four

The Product Side of Science

Subsequent to your interactions with Chapter Four, you will be expected to be able to ...

1. ... define scientific knowledge (product) as reflected in this section.
2. ... define (or compare, noting important likenesses and differences) facts, laws, theories, and concepts in science.
3. ... defend the statement that "Theories can never become laws."
4. ... explain why theories and laws can never have an absolute truth value.
5. ... communicate the scientific value of theories and laws. Further, be able to communicate the educational implications of theories and laws.
6. ... identify statements of scientific information as facts, theories and/or laws.
7. ... describe the utility (from an intellectual standpoint) of concepts in terms of their being:
    a. a means of organizing information into mental categories or "packages of descriptions and relationships."
    b. a way in which the human organism can analyze (mediate) new information in terms of what is already known about objects and events in the universe.
8. ... describe how b. (above) is dependent on a. (above).
9. ... explain why a broad range of accurate and fairly thorough concepts help a human being adjust to his environment.
10. ... explain why a concept held by a human being can be accurate and/or inaccurate and/or incomplete.
11. ... define or describe both inductive and deductive intellectual reasoning and compare the two forms.
12. ... diagram and explain the inductive and deductive intellectual processes involved in concept formation and the use of concepts in mediating (processing) new information. You will be expected to use an example other than the ones used in this reading.
13. ... identify the educational benefits of teaching for concept development.

14. … describe the pitfalls a teacher must guard against when inductively teaching for concepts.

15. … identify the criteria that help a teacher decide on whether to teach a concept inductively or deductively.

16. … name and describe the components of the learning cycle. Further, discuss how the learning cycle maximizes concept formation and application.

17. … explain why a science program totally devoted to the product side of science is an abdication of responsibility on the part of the elementary school teacher.

The Product Side of Science

Many of you who read this have experienced science in school from mostly a product standpoint. That is, in your science classes, the major component of science has been the teaching of knowledge.

Today, of course, science educators feel that knowledge is not enough—that there is more to science, and children should experience science in its full dimensions. Even so, knowledge in science is important, even though teachers in classrooms should not rationalize a strategy for teaching only knowledge. It is unfortunate that, when product is emphasized, this dimension of science sometimes deteriorates into the learning of facts without any regard for concepts, attitudes, or intellectual processes.

What is knowledge? Knowledge in science includes all of those data that scientists agree to be true or that knowledge that scientists have generated which allows hypotheses to be formulated and tested. The important thing to consider is that knowledge (product) is produced in empirical ways which allow man to trust the products derived. Knowledge is, then, what man perceives as empirical truth—the stepping stones to a broader understanding of the universe and its objects and events.

In general, knowledge in science might be described as a composite of facts, laws, theories, and concepts. The term data merely connotes those pieces or bits of information that are empirically derived and are the constituents of facts, laws, and theories. Concepts are a different matter—we would hope that they are supported by empirical data but, alas, often they are not, and they become victims of ignorance and prejudice.

Fact In Science

What is *fact*? A fact is merely something that is observable and/or measurable, and that scientists agree is true. Facts are largely based on man's faith in *empirical standards*—the qualities of careful observation and standard measurement.

Some examples of facts follow. Nitrogen comprises 79% of the atmosphere. The density of gold in grams per cubic centimeter is 19.3. Venus is the planet nearest to Earth. It is a fact that light travels at a speed of 186,000 miles per second. The speed of light has been measured. Scientists agree on the critical distance subsumed by a mile or a kilometer and they also agree on the interval of time known as a second. Once instruments were available for measuring how fast light travels, it became a relatively simple matter to do so. Of paramount importance is that numerous scientists are able to substantiate this finding. This is known as the scientific quality of *replication*. If an observation or a measurement cannot be replicated (repeated), it is mostly worthless. Of course, it might be worthy to the person who observed it, but if it cannot be repeated publicly, it is largely meaningless in science. To try to convince a scientist that a unique, private observation has scientific merit would be much like seeing a ghost and spending the rest of your life trying to convince your associates (or your psychiatrist) that you really did see this spectre and that it really exists.

A fact is something that is observable and/or measurable, and that scientists agree is true.

Even though facts are important in science, they certainly are not ends in themselves. They play a much greater role in the formation of concepts or in serving as foundations for laws and theories in science. Unfortunately, in many classrooms, teachers act as though a fact is a suitable end in itself. This is not a suitable approach to science with children. Facts tend to be forgotten quickly. Educational research indicates that only 35% of factual information taught to students is retained. Further, if facts cannot be related to a more important idea or used in a problem-solving situation, they are of little value to students.

Facts play a role in the formation of concepts and serve as foundations for laws and theories in science.

What follows is a discussion of other product components which have considerable implication for science education. The reader is asked to attempt to perceive the role facts plays in these products and to compare the intellectual value of these products to facts per se.

Laws

A *law* in science *deals with a specific category of phenomena—it is a statement of a relationship between phenomena. This relationship appears to be invariable under the same conditions.* Laws are the generalized statements of scientists which refer to particular records of scientific data which seem to indicate exact truths in science. One example would be the Law of Universal Gravitation. Another example of a law is Gregor Mendel's Law of Segregation which refers to the sorting out and reappearance of seemingly "lost" recessive characters in the offspring of hybrids.

Laws are principles or generalizations relating to the constants or regularities of happenings in the universe.

Mendel was a genius with plants and plant breeding. He noted, for example, that when he crossed short peas with tall peas that all of the offspring were tall. Thus, the short trait was apparently lost! However, when two hybrid offspring were crossed, the short (recessive) character reappeared in a ratio of one short to three tall. He found that one-fourth of the plants were pure tall, one-half were hybrid tall, and the remaining one-fourth pure short. Other traits in other hybrid crosses reacted in this same manner or ratio. This sorting out of genetic characters and their reappearance Mendel termed *segregation*. The principle involved became the Law of Segregation. Scientists have data from thousands of experiments that bear this out. Thus, we have a law which states something about the happenings in nature. We put a high degree of trust in the law even though we cannot say that this will happen ever on end! The same holds true for the laws of physics or the other laws of biology. They fit the picture we have of the universe until something comes along to modify this picture.

A law will allow us to predict what will happen under certain circumstances in the environment.

There occasionally comes a time when a discovery occurs in science that causes a law to be changed. Such was the case with the Law of Conservation of Matter. This law, simply put, stated that matter could neither be created nor destroyed. In the 1930s and 40s, this law was learned most carefully in high school and its "truth" faithfully accepted. Then came nuclear fission. We learned that matter can be transformed into immense amounts of energy, $E = MC^2$. We now, of course, do not accept the Law of Conservation of Matter as stated above. Physicists do believe, however, that mass is universally conserved as a property of matter and energy combined. The law was modified to accommodate this new discovery.

We can see that laws are *principles* or *generalizations relating to the constants or regularities of happenings in the universe*. A law will allow us to *predict* what will happen under certain circumstances in the environment. Laws are extremely valuable because of the data that support them. However, they are inductively derived and *no* inductive conclusion can have an absolute truth value because new data may eventually be found that will alter the conclusion and necessitate a new principle or generalization.

Theories

A theory is a generalized statement that acts as an explanation for large numbers of related facts, occurrences, or other phenomena in nature. Theories result as an observer views the universe and perceives many different data that seem to have a relationship to each other. The theories are the resultant statements that explain these relationships. Theories are, of course, inductively derived.

A theory is a generalized statement that acts as an explanation for large numbers of related facts, occurrences, or other phenomena in nature. Theories act as intellectual models for viewing the nature of the universe .

Theories have come and gone in science down through the ages. Some have persisted and some have failed to meet the test of time and further investigation, as they were constructed on weak logic foundations. An excellent example of a poor theory was Lamarck's theory of evolution proposed in 1809. Lamarck attempted to explain evolution on the basis of the idea that changes in an individual could be brought about by influences in its environment and that these could be inherited. Lamarck's theory explained, for example, that giraffes developed long necks by stretching them for food, generation after generation. Today we know that this could not be the case. The findings of genetic evolution just do not support the theory.

The Lamarckian theory of evolution changed many years ago due to the observations made by Charles Darwin, who took a world cruise on the H.M.S. Beagle. Darwin's observations on this voyage plus careful analysis of data afterwards resulted in a new theory of evolution, one that rocked the very foundations of the scientific community and one, by the way, that remains virtually unchallenged in the scientific community today. Simply, Darwin's theory was based on the idea of natural selection within breeding populations of organisms. The known facts of genetics, heredity, and adaptation bear out his thinking.

Theories act as intellectual models for viewing the nature of the universe (or a portion of the universe). These models provide a basis for scientific research. They pose a means of asking questions of the environment. Say, for example, that Lamarck's theory of evolution had received wide acceptance in the scientific community. Subsequent research into evolution would have been based on hypotheses related to that theory. Of course, eventually, scientists would have realized (and did) that Lamarck's theory (model) was unsound. A good theory tends to be substantiated by research findings. And, this is the case with Darwinian evolution, an entirely different theoretical model.

Theories, like any other scientific model, do not have absolute truth value. We find certain exceptions to many theoretical models in science. Such is the case with the cell theory in biology and the theory of population dynamics in ecology. Even though these theories are not absolutes concerning the environment, they still serve as extremely valuable models for viewing the universe. We know, for example, that the germ theory of disease, developed by Pasteur in the 19th Century, is not 100% valid. Yet, it was a major scientific breakthrough at the time and, today, a century later, the germ theory of disease is an accepted model used in research. Countless millions of human beings and domestic plants and animals owe their lives to a man who took time to view the universe with a different perspective.

Because the purpose of a *theory* is to explain a set of related phenomena, it can never become a law. Theories will remain theories forever, either being tested and receiving more credibility if evidence supports them or being possibly refuted if evidence contrary to the theory is unearthed. Laws, also, should not be confused with theories. The purpose of a law is to state (not explain) relationships between similar sets of phenomena. Laws may be modified because of new evidence and are not absolute because they are inductively derived.

Concepts

A very useful component of knowledge, particularly in science education, is the *concept*. Although many educational variations exist for definitions of concepts, an attempt will be made to keep the definition here as simple as possible. Let us refer to a *concept* as *the mental image one has of an object or an event or the relationships that exist between objects and/or events.* Some examples of scientific concepts are: "All matter is made up of atoms." "Celestial bodies move in predictable paths." "Living things are affected by their environment."

A concept is the mental image you have of an object or an event, or of the relationships that exist between objects and/or events. Your concepts are a result of your background of experiences and the evidence available for you to use.

Of prime importance is that a person's concept is his/her own—a private mental image generated from data fed into the intellect. This means that *no one can speak or hear a concept!* One can only communicate using language symbols to attempt to interpret a concept to another human being. Whether the human being subjected to the language input produces an appropriate concept is dependent on many factors.

One of these factors is the ability of the teacher and the learner to communicate effectively. Because concepts in science education are so terribly important, it becomes evident that *the use of language in communicating concepts may be one of the poorest means of developing conceptual ideas in the minds of human beings.* The potential for error is tremendous, and this is one reason why we cannot refer to concepts as always being empirically derived. Indeed, they may be anything but empirical!

A person's concept of a portion of his environment is tempered by and a result of his background of experiences and the evidence at his disposal. For example, a person with training in entomology certainly conceptualizes insects in a far different manner than a person with no training with respect to insects. The entomologist visualizes insects as a facet of the animal kingdom, classifiable, and of economic importance. The person with no training probably perceives many arthropods that are not insects as insects, sees no orderly manner in their classification, and relates them only to his own experiences, pleasant or otherwise.

Concepts are extremely useful in dealing with one's environment. They help the individual cope with the universe in a logical and rational manner.

It is obvious, then, that concepts can be erroneous — or correct but limited or incomplete. The educational implications here are tremendous. If teachers select the wrong information to use to teach for concepts, the likelihood of erroneous concepts being formed is maximized. If a teacher selects a narrow array of activities to teach for a particular concept, students will probably form limited (incomplete) concepts.

An example of conceptual development might be beneficial, and one can be found on the next page. Every intellectual discipline has a certain, organized structure to its information. This structure facilitates the understanding of the discipline and is often called the substantive structure of knowledge. In the science of ecology, for example, the "community concept" has, for many years, been a fundamental, rather complex concept used in the interpretation of ecological phenomena. In turn, the community concept itself is one with many bits and pieces of information impinging on it. Needless to say, the more knowledge a person has involved in his concept of "community," the more effective, meaningful and powerful the concept will be intellectually. In the presentation on the following page, we begin with a person who has either no ecological community concept or a very narrow one (although he may have a well-organized cultural community concept). Over time, this person's concept is broadened by the addition of new and unique ideas concerning community structure and interaction. This visual presentation, by no means, attempts to fully describe the variables operating in this scientific concept, but it does show how a concept can grow by the addition of new information. It also helps one see how some of the inherent knowledge in the concept *might* be organized.

Concepts are extremely useful in dealing with one's environment. They help the individual cope with the universe in a logical and rational manner. An example here might prove helpful. Let us reflect on the usefulness of a correct and fairly thorough concept of "science" itself. The human being with an erroneous concept of science will often give to science almost omnipotent powers—he will perceive science in an altruistic manner—he will see science as being synonymous with technology—he will see the scientist in a context that is almost totally foreign to the human one in which the scientist logically belongs. All of the above conceptual positions are faulty and could prove ruinous to any large population of human beings holding tenaciously to these ideas. The value of a correct concept concerning science and the scientist is important to each human being. It permits the individual to cope with science and society—as well as with his/her own social responsibilities—in a rational and productive manner rather than in a debilitating fashion.

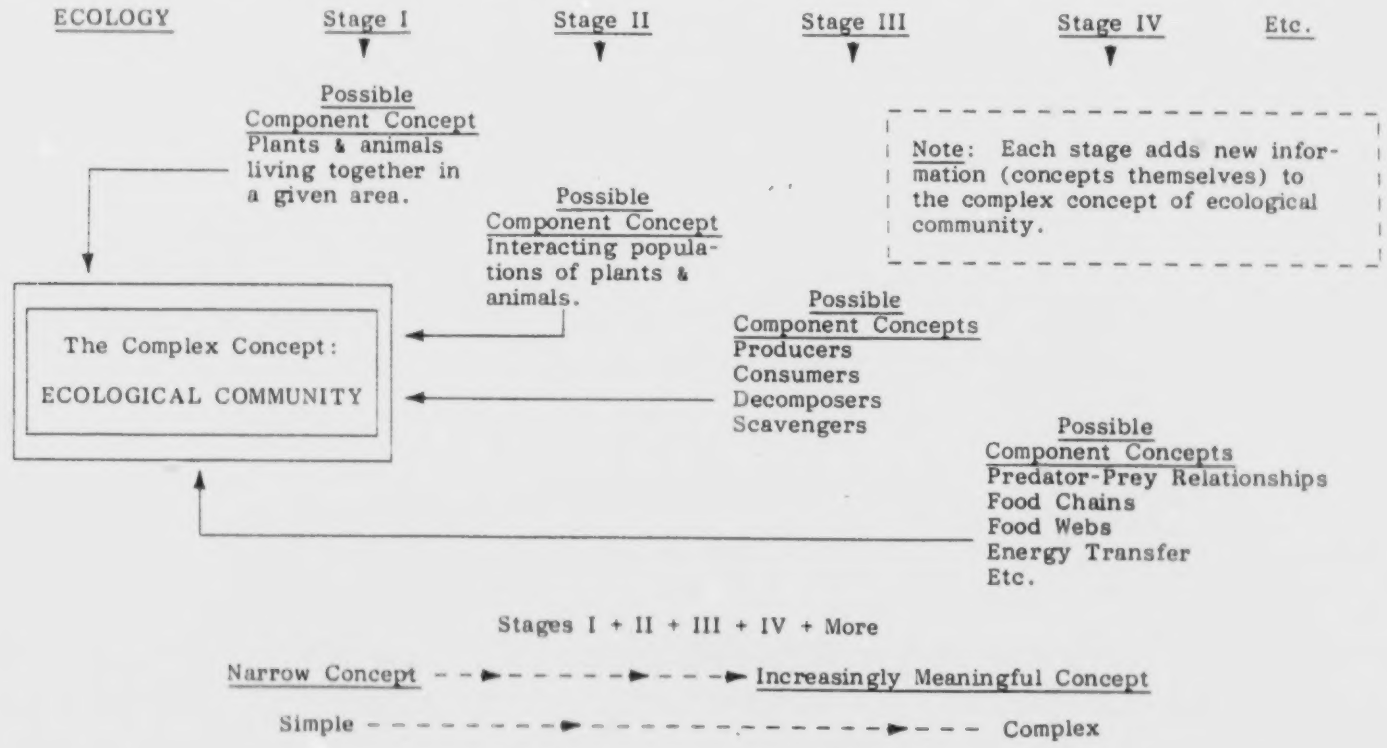
Concepts allow us to organize knowledge into useful mental categories or "packages of descriptions and relationships."

Correct and usable concepts also help a human being adjust to his environment. Concepts are, in fact, means by which human beings organize knowledge into useful mental categories or "packages of descriptions and relationships." They also provide a basis for the logical *mediation* and interpretation of new information as perceived by the individual.

How A Complex Concept Develops: An Example From Ecology

THE ECOLOGICAL COMMUNITY

The Discipline: Developmental Stages of increasing concept complexity



ECOLOGY

Stage I

Stage II

Stage III

Stage IV

Etc.

Possible Component Concept
Plants & animals living together in a given area.

Possible Component Concept
Interacting populations of plants & animals.

Note: Each stage adds new information (concepts themselves) to the complex concept of ecological community.

The Complex Concept:
ECOLOGICAL COMMUNITY

Possible Component Concepts
Producers
Consumers
Decomposers
Scavengers

Possible Component Concepts
Predator-Prey Relationships
Food Chains
Food Webs
Energy Transfer
Etc.

Stages I + II + III + IV + More

Narrow Concept - - ► - - - - - - ► - - - ► Increasingly Meaningful Concept

Simple - - - - - - - - ► - - - - - - - - - - - - - - ► - - - Complex

Some comments regarding *mediation* may help to understand this process. As new data or experiences are brought into the mental patterns of the individual, they are analyzed and interpreted in light of what is already known about the objects and events of the universe. That is, available concepts are used to determine if a reasonable interpretation can be made of the new information. If the new data are seen as being related to the already held concept, the data are interpreted (mediated) with the original concept and it is revised and/or expanded to account for this new data. If a concept is not available that allows for the interpretation of these data, a new concept must be generated or the information remains uninterpreted. If data cannot be handled in some logical manner, they remain as a discrepant event to the observer. This process of mediation is similar to the assimilation and accommodation principles postulated by Piaget.

As new experiences are brought into the mental patterns of the individual, they are analyzed and interpreted in light of what is already known about the objects and events of the universe.

One can see, then, that conceptual development is of critical importance to the humans if they are to be able to continually cope with all facets of their environment. And teachers are responsible for much of the conceptual growth of human beings.

One of the common complaints among teachers centers on the quality of concepts held by students in their charge. Students just do not understand this—or that—or the other thing! Of course it's usually the former teacher's fault unless the child is a kindergartner and then the fault is the miserable experiential background provided by the parents! A rational look at these complaints points a finger of suspicion at the school itself, and no teacher can avoid some responsibility for conceptual development in children. The school itself is organized in a manner that tends to force poor conceptual development in some areas. Teachers are likewise prone to use language symbols to the almost total exclusion of other methods in the development of conceptual ideas. This, of course, is a poor means of imparting accurate and thorough concepts.

Induction is a process whereby the person will pick up an assortment of separate pieces of information and put them together in some manner that makes them meaningful to the viewer.

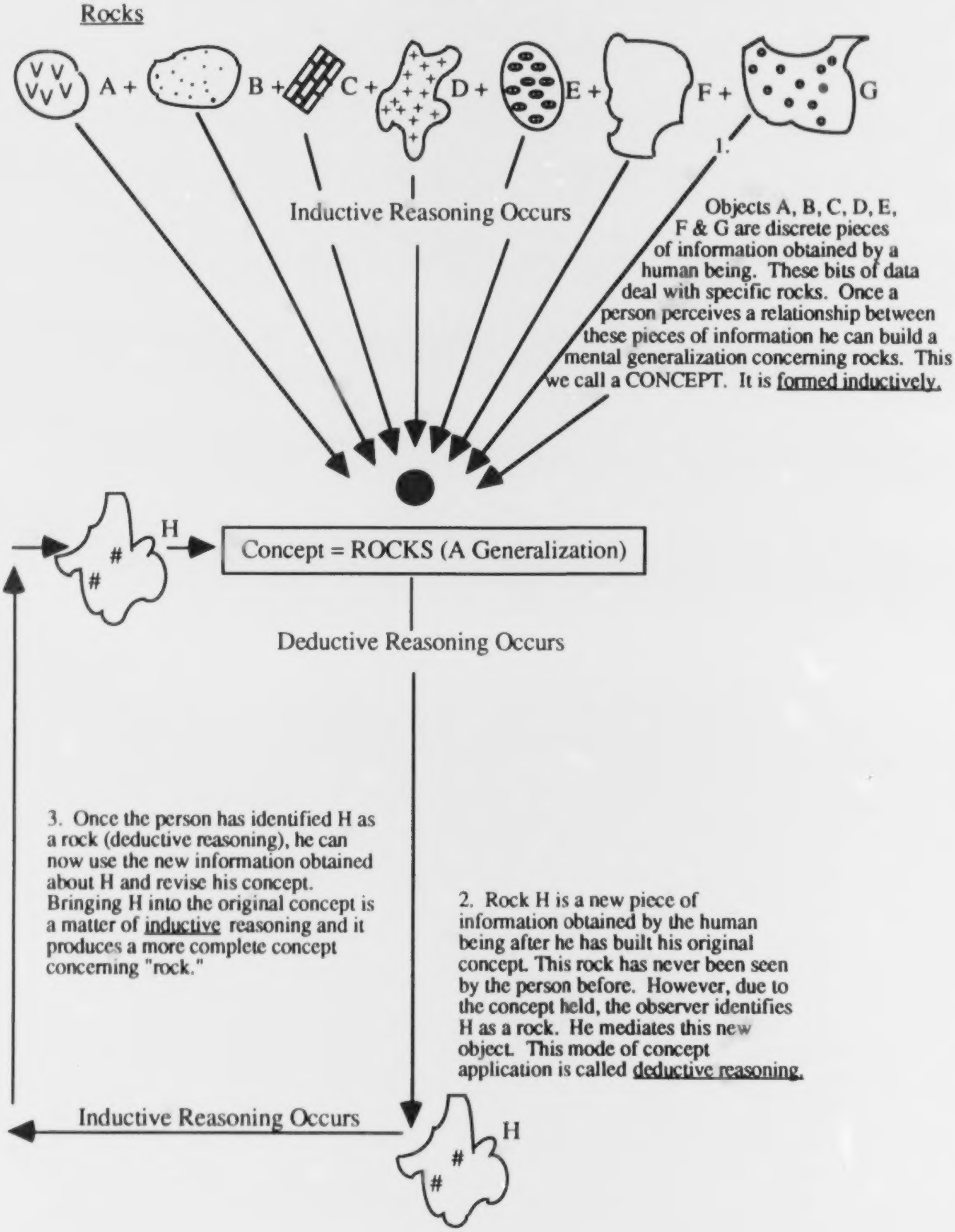
Concepts are largely formed by the human intellect via inductive reasoning. *Induction* is a process whereby the person will pick up an assortment of separate pieces of information and put them together in some manner that makes them meaningful to the viewer. The individual generates a mental image that alludes to the relationships between these pieces of information. Of course, there has to be some connection between the bits of information—at least in the mind of the viewer. At any rate, this mental image is what we call the concept. Any new piece of pertinent information perceived by the person holding the concept can force a revision or expansion of the concept to make it even more meaningful.

Deduction is the process whereby the intellect goes from the general (the concept) to the specific.

Similarly, people use or apply their concepts deductively. *Deduction* refers to the process whereby the intellect goes from the general (the concept) to the specific from a reasoning standpoint. A simple example would help here. All human beings have a con-

CONCEPTUALIZATION - ROCKS

An Example of Inductive and Deductive Reasoning


Rocks
A +
B +
C +
D +
E +
F +
G
Inductive Reasoning Occurs
H
Concept = ROCKS (A Generalization)
Deductive Reasoning Occurs
Inductive Reasoning Occurs
H

1. Objects A, B, C, D, E, F & G are discrete pieces of information obtained by a human being. These bits of data deal with specific rocks. Once a person perceives a relationship between these pieces of information he can build a mental generalization concerning rocks. This we call a CONCEPT. It is formed inductively.

2. Rock H is a new piece of information obtained by the human being after he has built his original concept. This rock has never been seen by the person before. However, due to the concept held, the observer identifies H as a rock. He mediates this new object. This mode of concept application is called deductive reasoning.

3. Once the person has identified H as a rock (deductive reasoning), he can now use the new information obtained about H and revise his concept. Bringing H into the original concept is a matter of inductive reasoning and it produces a more complete concept concerning "rock."

cept of human being. All of us have been getting vast quantities of data concerning the human organism almost from birth. Therefore, the inductively derived concept of human being is fairly well established. So what happens when you see a complete stranger on the street? You know almost instantly that this is another human being. You are, in fact, using your concept of a human being deductively here. Why don't you mistake this "animal" for a reptile, a bird, or an amphibian? It is simply because of your excellent concept of human being and your ability to identify even strangers as human beings. You do this deductively. You mediate the stranger into your intellect. In fact, if the stranger has some unique characteristics, you may then chance to alter your concept of human being. This revision is an example of inductive reasoning.

Your attention is called to the diagram on the preceding page. It visually represents the inductive process of concept formation using rocks as the concept material. It also indicates how concepts are deductively applied and inductively revised and/or expanded.

What Does This Mean For The Science Teacher?

It may seem somewhat foolish to spend so much the much time here concerned with conceptual development in a reading that is supposed to identify and discuss the product side of science. It is not foolish, however, because conceptual development is so tremendously important in science education and it behooves one to understand how it takes place. A teacher who is dedicated to meaningful and effective learning realizes that sound, broad concepts have great merit. Accurate concepts, especially those inductively formulated, have great meaning to an individual. They are retained much longer than facts. They are also of great utility to the human in that they assist one in intellectually handling large numbers of related information as wholes (generalizations) rather than individual pieces of data. Concepts are also valuable because they enable an individual to mediate new experiences and adjust to them intellectually.

The implications for science education (and other aspects of education as well) in terms of concept formation are apparent—*students must be given as many opportunities as possible to deal with the objects and events of science on a first hand basis in order to develop truly meaningful and accurate concepts*. It should be abundantly clear that personal experiences with objects and events are much more meaningful than surrogate experiences in language symbols. Similarly, the number and/or variety of experiences (as well as their accuracy) are important. One cannot form a good concept of insect, for example, by observing one insect or by being told by a well-meaning but unknowledgeable teacher that a spider or a tick is an insect. The same holds true for any concept that is important to human beings.

The writers have made a strong case for the teaching of concepts using an inductive teaching style. To teach for concepts in this manner necessitates classroom time so that students may experience a variety of related experiences that lead to sound concept formation. Teachers must invest preparation time in order to select sound activities that are experientially oriented. Teachers are often tempted to take "the easy way out"—to tell students a concept or to have them read a textbook that states concepts. Concepts can be taught in those ways, but the learning effectiveness is much less. Students will not be the active intellectual participants in formulation of concepts they read or are told. Meaningfulness is diminished and understanding may be reduced because of the predominance of language rather than experience.

As teachers, you must make a choice as to which concepts you decide to teach inductively and which should be taught in a deductive manner. Are there criteria that might help in that decision-making process? The authors of your worktext believe there are. Some of these, in question form, are:

Criteria For Teaching Concepts Inductively

- **Is the concept valuable from a general education perspective?**
- **Can the concept be taught inductively?**
- **Can the concept be taught via first hand experiences?**
- **Do I want the concept to have personal meaning for my students?**
- **Is the concept one that my students can transfer to other subject matter areas?**
- **Will the concept have utility for my students in everyday situations?**
- **Do I have knowledge of activities and/or information sources to make a valid selection of appropriate learning *experiences?***

What other criteria might apply? Feel free to add to this list.

The fundamental characteristic that is common to both children and science is that both are actively involved in interpreting the objects and events of the environment.
Gerald S. Craig

Can You Identify The Differences?

You are now ready to try your hand at discriminating among facts, laws, theories and concepts. The statements on the following page are examples of either facts, laws, or theories. They are statements excerpted from actual science textbooks. In front of each are two blanks. In the *first blank*, place an *F* if the statement is a fact, a *T* if the statement represents a theory, or an *L* if it exemplifies a law. If the statement also represents a concept, place a C in the *second* blank. Otherwise, place no mark in the second blank.

________ ________ 1. An object placed in a liquid is pushed up with a force that equals the weight of the liquid the object displaced.

________ ________ 2. Some diseases are caused by microorganisms invading a plant or animal and upsetting the natural bodily processes.

________ ________ 3. Every mass in the universe exerts a force of attraction on every other mass.

________ ________ 4. Charges on atoms arise from the presence or absence of electrons in the outer orbit of the atom.

________ ________ 5. Matter is composed of very small particles that are in constant motion. How much motion (energy) they possess determines the physical properties of matter (e.g., solid, liquid, gas).

________ ________ 6. One British Thermal Unit (BTU) equals the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

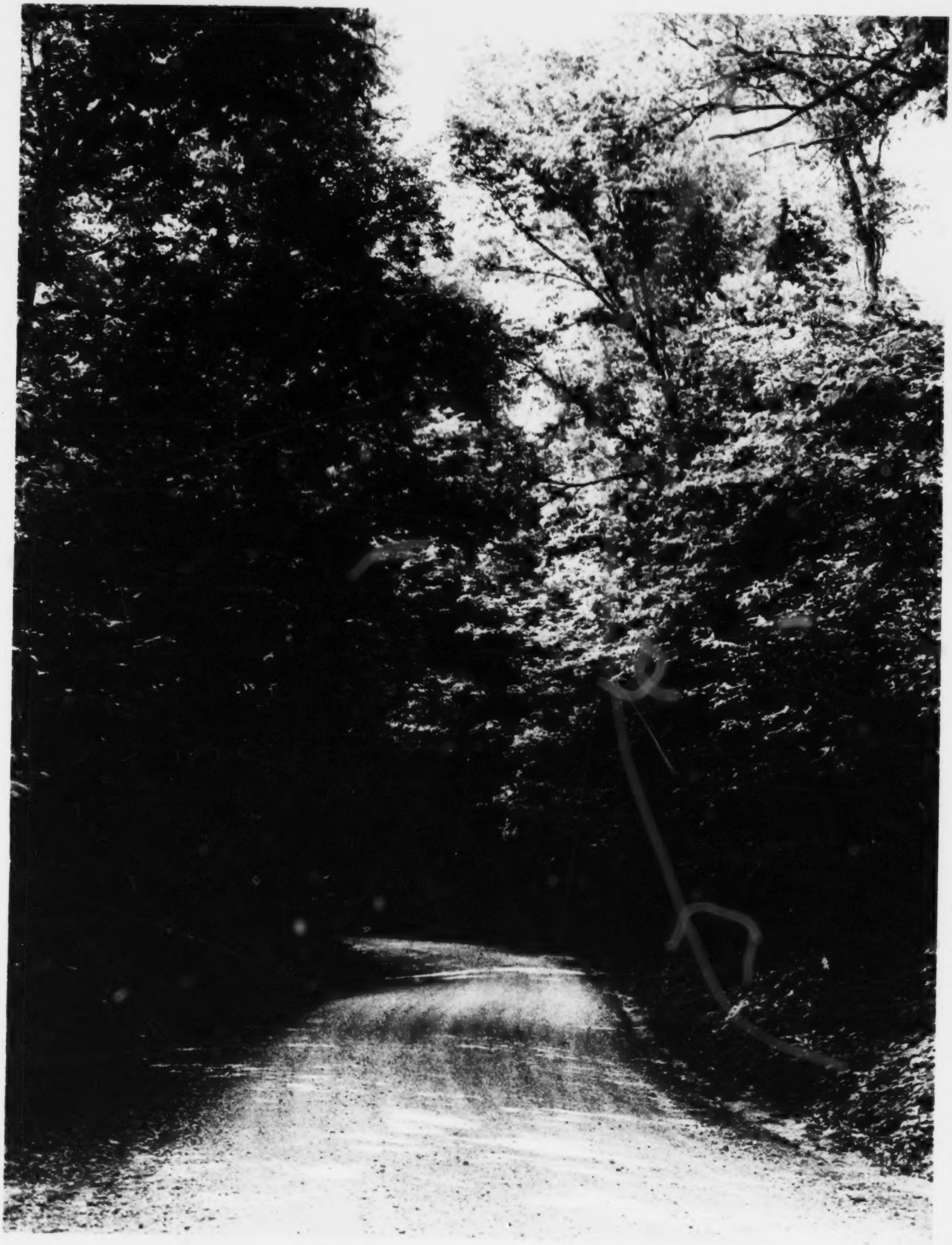
________ ________ 7. The environment causes changes in an individual and these changes are passed on to its offspring. (Note: This idea is not accurate).

________ ________ 8. For any gas, the pressure will increase when temperature is increased, given that the volume remains constant.

________ ________ 9. Environmental factors (e.g., food, space) tend to prevent living populations from either becoming very large or disappearing.

________ ________ 10. The specific gravity of gold is 19.3.

Answers to above exercise: The following statements are facts: Items 6 & 10. The following statements are theories: Items 2, 4, 5, 7, and 9. Statements 1, 3, and 8 are examples of laws. You should have placed a C in front of all of these statements since each could represent a mental image that an individual can have regarding objects or events in the universe or a mental image regarding the relationships between sets of data regarding similar sets of objects and events. Students can and will develop concepts regarding facts, laws and theories.



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Chapter Five

Models of Instruction

Science is built of facts the way a house is built of bricks,
but an accumulation fcats is no more a science than a pile
of bricks is a house."
Henri Poincare, La Dcience et l'hypothese

Upon completion of Chapter Five, you will be expected to be able to ...

1. ... write a rationale for using the General Teaching Model (GTM).
2. ... name the components of the General Teaching Model.
3. ... identify the features of an instructional objective.
4. ... recognize examples of acceptable instructional objectives.
5. ... distinguish between learning outcomes and instructional objectives.
6. ... construct a lesson plan or unit the follows the General Teaching Model.
7. ... identify the phases of the Learning Cycle.
8. ... explain how the Learning Cycle fits the
9. ... describe the purpose and implementation of each of these.
10. ... construct a lesson plan that follows the Learning Cycle.
11. ... identify the phases of the 5E Instructional Model.

Preparing Instructional Materials

In this chapter, we will focus on the development of lesson plans, instructional units, modules, packages, or whatever term you wish to use in describing a self-contained instructional "entity" for use in teaching something of importance to students (any age level). As a professional how do you make decisions about *what* to teach, *how* to choose your objectives, *how* to prepare for instruction, *how* to deliver that instruction, and *how* to evaluate the effectiveness of that instruction? Hopefully, this section of the worktext will help you in answering at least some of these critically important questions.

In any instructional planning or decision making process, it is crucial to know precisely what your educational goals are. Elsewhere in this worktext we present scientific literacy as the overriding goal of science education and a set of goal clusters felt to reflect a sound science program for literacy. You will recall that these goal clusters were: (1) personal needs, (2) societal issues, (3) academic preparation, and (4) career awareness. Elsewhere in the worktext we emphasize the fact that most science textbook programs do not teach to the bulk of these goal clusters. This means that, in most school settings, you will have to plan for and deliver instruction that goes beyond readily available, commercially prepared materials.

In order to plan for and deliver sound instruction for students, you need access to an instructional model that can be used in the development of lesson plans or instructional units. Needless to say, this model should be one that helps guarantee the validity of the material being produced. Such a model does exist, and it is strongly recommended that you become skilled in its use. This model is called the General Teaching Model—the GTM.

The GTM serves as an effective guide for planning any sequence of instruction in science as well as other content areas. The GTM serves for planning either deductive or inductive instructional sequences. There are specific teaching models developed by science educators that conform to the GTM guidelines and offer particular value in facilitating student concept attainment in science. Two of these models that will be described later in this chapter are the "Learning Cycle" and the "5E" instructional model. Both these models emphasize an inductive approach to learning as described in Chapter Three of this worktext.

The General Teaching Model (GTM)

The General Teaching Model (GTM) was developed at Southern Illinois University at Carbondale in the 1970s by Roger E. Robinson and David T. Miles. It was revised in a document published by the SIU-C School of Medicine in 1979. The GTM has received national and even international recognition as one of the best devices available for improving instruction at *all grade levels* of education, in *all subject matters*, for *any length of instruction* from a few minutes to a semester.

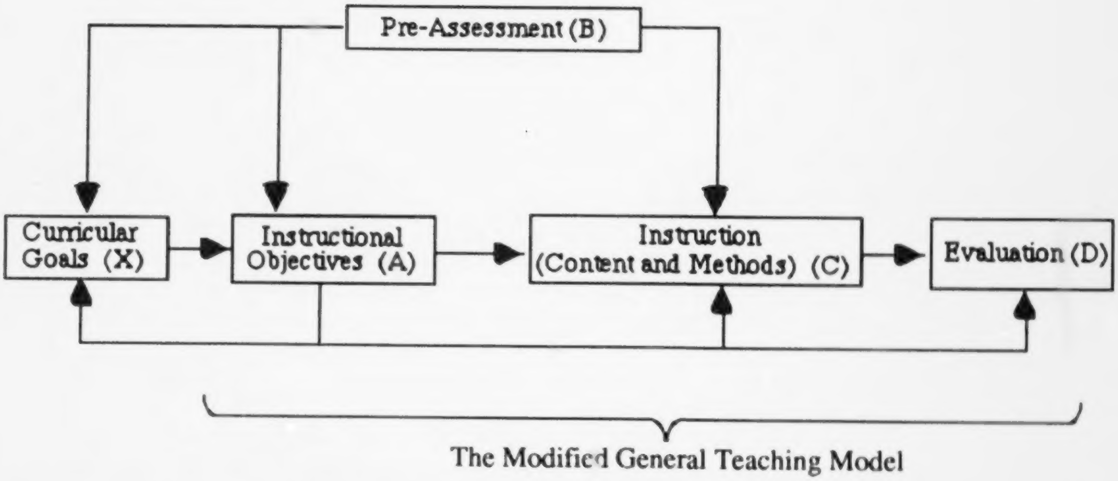
The GTM is seen as having two major functions. These are: (1) guiding teachers through the major steps of designing and carrying out instruction and (2) providing a structure (model) with which to view and examine the teaching process. The original developers point out that good teachers will find considerable similarity between the GTM and the procedures they employ in teaching. Viewed in this way, the GTM can be described as an attempt to make explicit what makes an effective teacher effective.

The authors of your worktext would like to take the above comments one step further. The GTM, if used properly, brings *integrity* to the teaching process. Far too often we observe teachers (elementary, secondary, college professors) who advocate a particular set of objectives, teach for what is apparently another set of objectives and then evaluate students on a mysterious third set of objectives. Not only is this poor teaching as such, it is totally unethical in that students do not know what it is they are expected to learn and, therefore, do not achieve at a level that is commensurate with their potential. This waste of human talent and intelligence could, in large part, be avoided if teachers would only analyze their own instructional process and learn to apply the GTM rigorously and consistently.

Teachers sometimes complain that the GTM takes away from their creativity and academic flexibility. To some extent this may be true. However, the GTM does *not* act as a guide for what will be taught, does *not* dictate instructional methods, and does *not* dictate evaluation strategies. Even using the GTM, the teacher must decide what is to be taught, how it will be taught, and how the entire process will be evaluated. These decisions rest with the teacher—the GTM only guarantees the integrity of the instruction and then only if used properly.

Now, let's take a look at the GTM section by section. This may produce a better understanding of it and help begin the development of those skills needed for implementing this model.

The Modified General Teaching Model (GTM)
And Its Relationship To Curricular Goals


Pre-Assessment (B)
Curricular Goals (X)
Instructional Objectives (A)
Instruction (Content and Methods) (C)
Evaluation (D)
The Modified General Teaching Model

This figure diagrams the modified GTM (A, B, C, & D) plus its relationship to curricular goals (X) (e.g., Project Synthesis Goal Clusters/Subgoals). A, C, & D are the critical components of this model which must be considered in all cases. Pre-Assessment (B) must also be considered as an integral component when needed in the instructional process. Note the inter relatedness of all components. These relationships must constantly be respected in any instructional development process in order to maintain any semblance of instructional validity/integrity.

Instructional Objectives (A)

Instructional Objectives (A) →

Instructional objectives are critical to the entire process of curriculum development and instruction. Instructional objectives establish what the learner is to learn (i.e., what the teacher is to teach). Of course, the *selection* of instructional objectives is a matter of considerable importance. Although this topic is not dealt with in depth in this chapter, it is important to remember that one cannot go about the business of selecting objectives in an intuitive manner. There must be some serious educational premise for the selection of objectives. Among the most important considerations are:

1. Are the objectives being considered consistent with the *goals* of this course (e.g., Project Synthesis Goal Clusters)?
2. What should the students be able to *do* subsequent to the lesson, unit/module?
3. What *prerequisites* are demanded by the content being taught in this lesson, unit/module?
4. What instructional resources are available to the instructor of this lesson, unit/module?
5. What must this instruction provide students in order for them to be successful in subsequent grade levels?

Generally speaking, objectives can be characterized as being one of three types (domains) of behavior. These three domains include the affective, cognitive, and psychometer domains and are briefly described below.

Domains of Behavior

The Affective Domain: This domain deals with emotions or feelings. Here we run into descriptions associated with things like values, attitudes, interests, motivation and appreciations.

The Cognitive Domain: The cognitive domain includes cognitive knowledge and cognitive skills. Cognitive knowledge deals with what an individual knows (e.g., a particular body of knowledge, conceptual structure). Cognitive skills are those intellectual attributes that permit a learner to enter into problem-solving, information processing, evaluation and the like. Cognitive skills are represented by such things as inferring, classifying, hypothesizing, interpreting data.

The Psychomotor Domain: This domain deals with attributes associated with physical movement (i.e., some mode of physically acting on the environment). There are a number of levels of accomplishment associated with the psychomotor domain (e.g., imitation, naturalization).

Objectives do not always fit exclusively in one of these domains. Sometimes, one can find some element of two or more domains in an objective. Still, it is usually possible to determine which domain is predominately displayed in an objective. This permits the instructional designer to determine whether there is an adequate number of objectives which fit the domains needed in the development of particular learner behaviors. Instructional objectives should contain three elements. These are:

- The *what* of the objective.
- The *how* of the objective.
- The *how much* of the objective,

In other words, an instructional objective specifies*what* the student is supposed to do, *how* he or she is to do it, and *how much* of that behavior is expected.

Concept: Rocks on the surface of the earth are attacked and decomposed by the agents of weathering.

Let's see how this might work. Assume for a moment that you are teaching sixth grade science and one of the units deals with geologic processes. One of the major ideas (a concept) in the unit might deal with the weathering of rocks. You prepare a set of objectives for this unit and the one dealing with this concept looks like the following:

> *Objective: Upon completing the unit, the student will be able to define weathering in one written sentence and list three agents of weathering.*

Does this objective tell *what* the student should do? Does this objective tell *how* the student should meet the objective? Does this objective state *how much* of the behavior is expected? The answer to all these questions is "yes." Now, the question is: Is this a good objective? It certainly meets the three criteria established for writing objectives, doesn't it? But, the question remains: Is this a good objective? The test for whether or not an objective is "good" goes well beyond whether it meets the criteria for writing an objective. One must also determine whether the objective tests what it is supposed to test (i.e., does it measure what is intended)? In the case of the weathering objective, the student is asked for a definition and an identification of three forms (kinds) of weathering. If the teacher wants to know if the student understands the processes involved in weathering, the objective falls far short of accomplishing this. Further, if this content is important, the teacher should probably want to determine whether the concept of weathering has actually been learned. Therefore, the original objective is inadequate and needs to be rewritten. How would you go about revising it?

First, you would need to determine how you could measure whether the student understands the concept of weathering. Second, you would have to construct an objective or series of objectives which would permit you to observe some level of comprehension on the parts of the students. Your new objective(s) might look like the following:

Subsequent to the unit on geologic processes, the student will be able to . ..

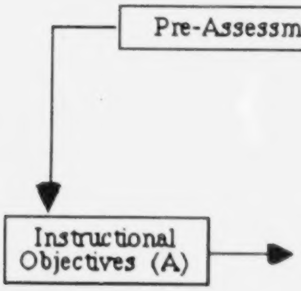
> *1. ... physically demonstrate three important agents of weathering through construction and testing of a weathering simulation model.*
>
> *2. ... Orally explain how their model simulates each of these weathering agents attacking rocks at the surface of the earth .*
>
> *3. ... Explain, in paragraph form, why weathering takes place only where rocks are exposed at or near the surface of the earth's crust.*

Are these objectives more adequate for the task at hand? Probably! Although there might be differences of opinion concerning how this concept acquisition should be measured, there is no question that the three objectives written above would better tell the teacher whether the students had actually conceptualized the ideas related to weathering.

The writing of performance objectives is no easy task. It can be a frustrating and difficult experience. Even so, the use of objectives which are well thought out and well written can bring a great deal of integrity to the teaching process. They do, in fact, determine what the teacher is to teach and what the learner is to learn . . . all in all, a pretty good prescription for effective instruction. (Science methods students needing experience with the evaluation of, analysis of, or writing of performance objectives should use Appendix B in this worktext.)

Within the past several years a national trend toward what is known as "outcome based education" has received media attention. As someone preparing to become a teacher you should be familiar with what is known as a **learning outcome**, since in some districts and states it has virtually replaced the performance objective as the focal point of lessons or instructional units. A learning outcome is basically similar to an objective but it is much broader. It is intended to explore both the range and depth of skills related to a curricular goal cluster or area. A learning outcome often cuts across fundamental areas of learning (not just science) and involves community or home based tasks or problems. Learning outcomes are intended to describe in a general way what all learners should be able to do. Learner outcomes are assessable often through complex generated student responses. A learner outcome contains a preface (condition), a verb (for assessment tasks), and the skills or content to be demonstrated. For example, "As a result of their schooling students can effectively communicate in both written and spoken forms" is a learning outcome. "As a result of their schooling students can develop and test a hypothesis for a stated problem" is also a learning outcome. Learning outcomes may focus on students' knowledge or understanding, or their ability to analyze, synthesize, evaluate, perform, demonstrate or even interact with others.

Pre-Assessment (B)



Two sound reasons exist for using pre-assessment. One use of pre-assessment is to determine whether students have the prerequisites necessary for what the teacher anticipates teaching. This would determine whether the teacher needs to revise his or her instructional plans. Pre-assessment here would ascertain if there were individual students who needed remediation before entering into the content or skills being addressed. If this was the case, remedial activities could be designed for individual students. A second use of pre-assessment is to determine how much of the content in the forthcoming unit students already know. Can the teacher omit any of the objectives for this unit for either the entire class or individual students? If this is the case, instructional time could be shortened and/or made more efficient.

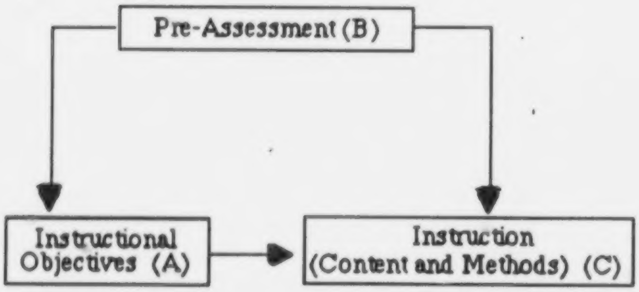
In the original GTM, Robinson and Miles place Pre-assessment in line with all other components (i.e., they did not bring it out of a linear pattern as the authors of your worktext have done). Why did the authors alter the position of Pre-assessment in the

GTM? They certainly do not disagree with the use of pre-assessment in an instructional setting. However, they do feel that as important as Pre-assessment is, it *need not* be used in every situation when a new lesson or unit/module is being introduced. This is particularly true when instructional units are sequential in nature or where the instructor knows the students well. Therefore, in the GTM diagram Pre-assessment is shown above the other three components.

How does one go about deciding how to pre-assess? Although this depends considerably on the content being covered and the teacher's familiarity with the students, a number of strategies could be employed. One strategy for pre-assessing is simply to choose assessment items or tasks from those which would be used in the evaluation phase (see D below) of instruction and use these. If there is a wide range of such items, one would have to be very careful to choose those which would represent the terminal behaviors being worked toward. If there is a large selection of items representing a limited amount of content, then a random selection of items might suffice. Another strategy is to construct assessment items or tasks which parallel evaluation items and use these in pre-assessment. This avoids some problems associated with using the same items twice.

In situations where the lesson or unit/module is short-term in nature, less extensive pre-assessment may be required. At times the teacher may simply want to hold a brief discussion concerning the content with the class in order to determine the general level of student preparation for the content. Individual interviews with students have also been suggested as a means of pre-assessment. This strategy would be particularly useful in classrooms where instruction was individualized.

Instructional Procedures (C)


Pre-Assessment (B)
Instructional Objectives (A)
Instruction (Content and Methods) (C)

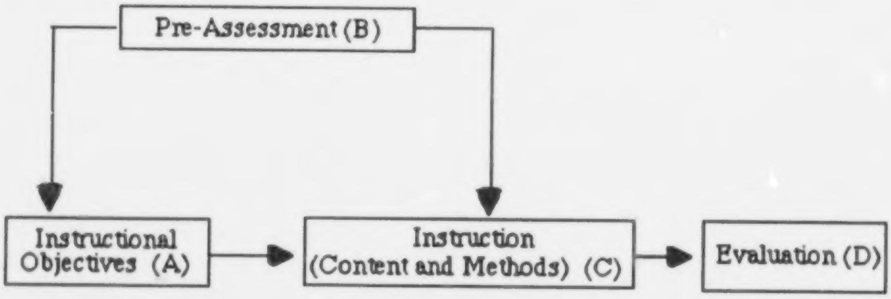
What kind of instruction should be used after the objectives have been written and pre-assessment completed? Of course, there is no simple answer to this question. Choosing the proper instructional strategy depends on which will be the most effective and most efficient means for getting students to achieve the instructional objectives or learning outcomes. This is controlled by a number of factors including the teacher's repertoire of skills, the instructional materials available, the kinds and ages of the learners, and the setting(s) available for carrying on the instruction (e.g., laboratory, regular classroom, outdoor facility).

A wide variety of instructional strategies are available. From this array of strategies, the teacher could choose the one (or more) that would be appropriate. Among effective strategies are: directed inquiry, open-ended inquiry, tutoring, teacher demonstration, lecture and/or discussion, independent study, collaborative groups, computer-based instruction, student journals and reading. It is evident that all of these are not appropriate for a particular instructional need, or for specific age groups or grade levels. Thus, careful planning is once again extremely important.

Once the overall instructional strategy is chosen, it is the teacher's responsibility to meet certain criteria for maximizing learning. In most situations a number of instructional principles should be utilized as a part of the instructional process. Research into learning indicates that many principles have proven to be helpful to the learning process. Among these are:

- *Pre-learning preparation:* . . . the use of advance organizers in order to direct the learner's mind toward that which he/she should be learning.
- *Motivation:* . . . promoting a desire to achieve the objectives.
- *Providing models of terminal performance:* whenever possible, students should be shown examples of what they are to produce/do subsequent to instruction.
- *Active responding:* . . . students need to do what they are expected to learn to do (i.e., it is what learners do that determines the learning that takes place).
- *Practice:* . . . if a new behavior is important, the learner needs to use it repeatedly in order to retain it over the long term.
- *Knowledge of results:* . . . learners need to have prompt and frequent input concerning their level of success and be put back on track whenever they falter in their search for mastery of the objectives.
- *Graduated sequence of subject matter:* . . . what is to be learned should be organized in a hierarchical manner from simple to complex or from familiar to the unfamiliar.
- *Providing for individual differences:* . . . teaching content in a manner that permits learners to proceed at their own pace, given that human beings learn at different rates.
- *Social and personality factors:* . . . research indicates that a teacher's personality and social skills make a tremendous difference in instructional effectiveness.

Evaluation (D)


Pre-Assessment (B)
Instructional Objectives (A)
Instruction (Content and Methods) (C)
Evaluation (D)

Evaluation is typically conducted at the end of a lesson or unit/module. Evaluation usually involves the use of some type of assessment tasks or items to measure the acquisition of knowledge, skills, or attitudes. Certain objectives or learning outcomes can, of course, be measured during the course of instruction (e.g., via observations of participation in labs, products produced for particular assignments, oral recitation). The instructor must determine when learners should be evaluated and how evaluation should take place.

Two major ideas associated with consistency and effectiveness appear crucial to the topic of evaluation. These ideas are discussed below.

Evaluation Should Be Consistent With The Objectives For The Unit . . .

Does this mean that the teacher must evaluate every objective? Not necessarily. It does mean, however, that the teacher must not enter into an "apples-oranges" phenomenon (i.e., stating an objective in a particular way and then evaluating in a completely different manner (one unexpected by the students)). An example might prove helpful. Suppose you had written an objective requiring the ability to compare and contrast characteristics of amphibians and reptiles. Then you write one multiple choice question asking for the identification of reptile characteristics and another for amphibian characteristics. Would this suffice? Absolutely not! In this instance you are asking the student to recall knowledge of the characteristics of the two groups of organisms—not to compare them one against the other. The original objective is one that is skill based whereas the test questions are knowledge based.

Evaluation Should Be Used To Measure The Effectiveness Of Instruction . . .

This idea is truly an important one and also one that is often ignored by teachers. How well students perform on an evaluative instrument indicates how effective instruction has been. Therefore, teachers should always look carefully at the results of evaluation to analyze as precisely as possible the effects of instruction. If evaluation results indicated unsuccessful instruction, it is probably the result of one of the following:

- Students lacked the prerequisites necessary for the successful completion of the unit/module.
- Instructional activities were not designed adequately.
- Instructional activities were not implemented adequately.
- The evaluation measure was invalid (i.e., it was not measuring what it was supposed to measure).

In the final analysis, evaluation either during or subsequent to instruction (or both) should indicate to the teacher how successful instruction has been. If unsuccessful, objectives need to be revised, or instruction needs to be changed, or evaluation needs revision, or all of the above. It is truly important to design instruction so that as many students as possible achieve as many objectives as possible while, at the same time, retaining a positive attitude toward learning.

A Lesson Illustrating the Application of the GTM

The writers of your worktext are of the opinion that you might appreciate an example of how the GTM would look in actual practice. One example exists in the layout of this worktext. Consider the presence of performance objectives in this worktext, the material presented in each chapter, what takes place in class, and how you are evaluated. This is one example of an effort to design an entire course based on the GTM. Another example, an abbreviated portion of a unit on adaptation, is presented below. Let's see how this might lay out.

THE UNIT: ADAPTATION

THE GOAL: Students will learn that organisms are adapted for survival in the environment in which they live.

PERFORMANCE OBJECTIVES:

1. ... orally describe how some prey organisms are adapted for survival through protective coloration.
2. ... identify or write at least six examples of organisms that are able to survive because of protective coloration.

PRE-ASSESSMENT:

Name two prey organisms that are helped to survive because they are a particular color in their environment. Explain how these colors increase survival chances for these organisms.

INSTRUCTION:

- Definition and discussion of protective coloration in prey organisms.
- Examples and discussion of prey organisms protected through protective coloration plus examples drawn from learners.
- Bulletin board w/colored photographs of examples of protective coloration.
- Outdoor laboratory using a variety of dyed—colored—toothpicks (green, red, yellow, blue, and natural wood color), twenty of each color, scattered onto a grassy area 5 meters by 5 meters. Three "predator" learners from the class are given one minute to retrieve as many of each color as they can. Data recorded and analyzed back in the classroom. Discussion following, concluding that some colors in a grassy plot would be more effective than others for escaping predators.
- Summary discussion to determine whether learners seem to have the concept, as well as a substantial number of examples.

EVALUATION:

1. In a written paragraph, describe how protective coloration helps certain prey organisms survive in their environment.
2. List six separate prey organisms which are helped to survive because they have developed protective coloration.

In the lesson displayed above, is there consistency between the elements (i.e., between the goal, objectives, pre-assessment, instruction, and evaluation)? Will the evaluation measure what the instructor intends to measure? Should there have been one or more additional objectives? In order to answer that question, we need to look closely at the lesson. The lesson demonstrates how the components of the GTM fit together and how the GTM relates to educational goals. A substantial amount of consistency exists between the elements. The question concerning whether there should have been one or more additional objectives can only be answered in terms of the extent to which the teacher chose to develop the concept and in terms of the age and background of the learners. The writers of your worktext would have probably added an objective dealing with the effect of protective coloration on the survival of a species as a whole. This would have necessitated additional instruction and a more thorough understanding of the concept of the variables associated with the continuation of survival for a species rather than for individual organisms. This decision, however, is one depending on the background of the teacher and the maturity of the learners.

The Learning Cycle

The Learning Cycle is an inductive instructional model for facilitating student learning of science concepts. The model was originally designed to help translate Piagetian theory into a classroom teaching methodology for science. The instructional techniques incorporated into the learning cycle arose from the "guided discovery" teaching research of Atkin and Karplus and the development of the Science Curriculum Improvement Study program by Karplus and others at the University of California, Berkley. Over the past thirty years the learning cycle has been used in many other science curricula and programs. Recently, the work of Lawson, Abraham and Renner has incorporated the elements of the learning cycle into an emergent theory of human learning. The learning cycle is now being characterized as a "constructivist process" for fostering conceptual change in students.

The Learning Cycle is an inductive instructional model for facilitating the student learning of science concepts.

The learning cycle is a three "phase" approach to instruction. Although these phases have been give different names over the past thirty years the purposes of each have largely remained intact. The worktext authors prefer the terms of **exploration, concept introduction** and **concept application** to designate the three phases of the learning cycle. These terms were used by Karplus and others early in the development of the model. The learning cycle may be viewed as an example of a specific teaching model for science that meets the criteria of the GTM. As you will see in the discussion that follows one or more objectives, or learning outcomes, are specified in a learning cycle lesson, students are involved in activities that effectively pre-assess their knowledge, various instructional modes are implemented and student progress is evaluated.

This sequence of three instructional phases is a unique feature of the learning cycle. Research supports the order of and necessity for each of these phases of instruction in learning cycle lessons. Each of the phases will be described below in terms of its purpose and how it may be implemented.

EXPLORATION involves students in making observations or collecting data that will lead them to become mentally engaged with a lesson concept. This is often done through "hands on" experiments or direct observation of objects or events. Frequently,

EXPLORATION involves students in making observations or collecting data that will lead them to become mentally engaged with a lesson concept.

discrepant events (things that don't happen as expected such as a can that rolls backwards) are used for exploration. Any kind of interesting objects or events may be used to stimulate students to discover patterns or relationships or identify variables. The direct learning experiences of the exploration phase occur with teacher guidance but not step by step direction. The role of the teacher is to manage and facilitate student interaction. Exploration that occurs in collaborative groups (four children with shared materials) is effective for upper elementary students, while the "working alone together" (tables of children with their own materials sitting in proximity) approach is effective for early elementary students.

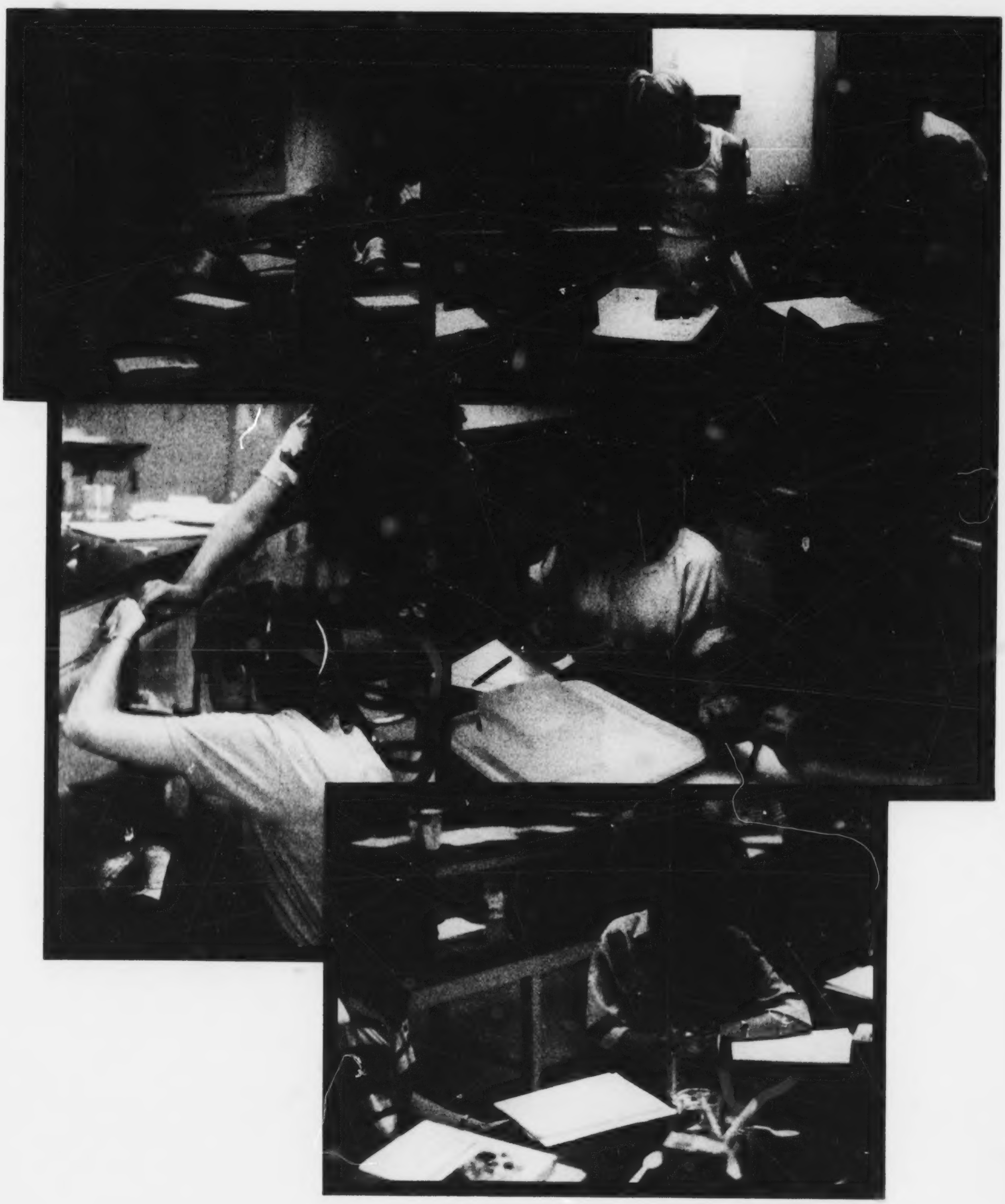
Typically one third or more of the time allotted for a lesson may be devoted to exploration. During exploration student curiosity and creativity should be encouraged. "What might you try?" and "What did you find?" are key questions for a teacher to ask students during exploration. Exploration gives students a chance to compare their understanding of a concept or phenomena with reality, or simply to start to develop a concept for the first time. The exploration of a learning cycle lesson may build upon the application phase of a previous learning cycle lesson.

Notice that in the Simple Circuits learning cycle lesson that follows, the exploration phase consists of students attempting todiscover if and how they can make a bulb light with one battery and one wire. Students are asked to observe and make drawings of what they try but are not given specific directions about how to make a bulb light. The teacher may use questions to guide the students but does so sparingly. During the early stages of exploration many, if not most, of the students realize the do not already know how to make a bulb light and thus will be motivated to learn how to do so. The teachers observation of the students working with the batteries, bulbs, and wires serves a **pre-assessment** function. As the students work with the materials to achieve a **performance objective** they are involved with indirect **instruction.** Three parts of the GTM are attended to in the exploration phase of this lesson!

CONCEPT INTRODUCTION involves the teacher in helping students to clarify and put a "name" on the lesson concept. In effect, students are introduced to the lesson concept. Notice that concept introduction occurs midway through not at the beginning of a learning cycle lesson. The concept is formally introduced, or explained, to students only after they have had time for appropriate and mentally engaging hands on exploration related to the concept. This introduction of the concept is not entirely expository or teacher centered although the teacher tends to lead this phase of the lesson.

The observations made or data collected during the exploration phase of the lesson is interpreted by the students with the help of the teacher. This often done by the teacher raising questions for consideration by the entire class. Perhaps collaborative student groups are asked to report to the entire class the observations they made during the exploration phase of the lesson. Through the use of questions students are guided to the lesson concept. "Why do you think that?" or "What does it mean?" type questions are often asked during concept introduction. The concept name and associated terminology is formally introduced to the students near the end of

CONCEPT INTRODUCTION involves the teacher in helping students to clarify and put a "name" on the lesson concept.



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this phase. Much of this phase of a learning cycle lesson involves the teacher working with the entire class at once.

In the concept introduction phase of the Simple Circuits learning cycle lesson that follows students are asked to observe chalkboard drawings of different circuits and to predict if the bulb in each of the circuits will or will not light. Students are told they may look at their own drawings, made during concept exploration, to help in making these predictions. After a period of time the teacher asks students to state their predictions about the different circuits. As predications about circuits are voiced by students, the teacher asks for reasons as to why the bulb will or will not light in a particular circuit. By probing students reasons for making certain predictions about particular circuits, the concepts of open, closed, and short circuits are developed. The teacher labels the drawings that represent open, closed and short circuits and reviews criteria for identifying each. The concepts of open, closed and short simple circuits is thus introduced. During the concept introduction phase of this learning cycle lesson students experience both indirect and direct **instruction.** Since the instruction matches the lesson objective the integrity of the GTM is maintained.

The CONCEPT APPLICATION phase involves the students in using the lesson concept in a new or different context to show extended understanding.

The CONCEPT APPLICATION phase involves the students in using the lesson concept in a new or different context to show extended understanding. Perhaps they will be asked to make and explain predictions about what will happen in experiments or activities when a variable is changed. Students might be asked to identify similarities in "new" objects or events with ones previously studied. Students should be required to use their understanding of a concept to deal with some related but new question, prediction, or situation. Upper elementary students may be challenged to deal in abstract application of a lesson concept, while early elementary students are typically involved in concrete concept application. Questions like "What will happen if...?" or "Based on what you have learned can you find, can you classify, or can you predict...?" are typical questions teachers ask to students during concept application. Students may work in collaborative groups or alone during this final phase of a learning cycle lesson.

The Simple Circuits learning cycle lesson begins on the following page. In the concept application phase of that lesson, the students are given a worksheet with numerous drawings of simple circuits, asked to predict for each if the bulb will light and to name the type of circuit. Students might also be asked to work with a microcomputer based circuit simulation program to test or demonstrate their understanding. As a take home application assignment students might be asked to find different examples of simple circuits in and around their homes. This phase of the lesson may also serve as extended **instruction** or **evaluation** of the objective of the lesson in keeping with the GTM Note that the concept application activity in this learning cycle lesson on simple circuits lays the foundation for the exploration phase of a subsequent lesson on series and parallel circuits.

The 5E Instructional Model

We will briefly describe another inductive instructional model that fits the GTM. The "5E" or BSCS model was developed byBybee and Kuerbis and others in the Biological Science Curriculum Study. The model is an extension of the learning cycle in many ways but contains more phases or components and takes a step closer to the constructivist oriented approach to teaching and learning. The 5E model is gaining acceptance and application in innovative curriculum and teaching materials

Each of the steps of the 5E model focus on kinds of student action. A 5E lesson starts with **engagement,** something that presents students with a task or puzzle that gets them cognitively involved with the lesson. The engagement activity or problem is context and student needs sensitive and aims to link previous experience with lesson events. **Exploration** follows engagement in a 5E lesson. This is much the same as an exploration in a learning cycle lesson, with a hands on activity designed to show gaps in understanding and motivate learning. An **explanation** is the third step in a 5E lesson and serves the same general purpose as the concept introduction in a learning cycle lesson. This step is mostly teacher directed and aimed at resolving misconceptions and introducing terminology. **Elaboration** is phase four in a 5E lesson and is aimed at involving students in extending their understanding of the lesson concept. This is similar to the concept application phase of a learning cycle lesson. Students may work in groups to devise the best approach to a newly given problem or task related to the lesson concept. The 5E model has a separate **evaluation** component as its fifth and final part. Students come face to face with the quality of their understanding of lesson concepts and teachers do this as well using authentic as well as traditional means.

The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter . . . O that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity.

Benjamin Franklin—1780

LESSON CONCEPT: SIMPLE CIRCUITS

TARGET GRADES: Fourth through sixth.

GOAL AREA:

As a result of their schooling, students will have a working knowledge of the concepts and basic vocabulary of the sciences and their application to life and work in contemporary technological society (Illinois State Goal #1 in the Biological and Physical Sciences).

LEARNER OUTCOME:

As a result of their schooling students will be able to demonstrate their ability to apply scientific thinking skills, including those of observation, inference, and prediction.

PERFORMANCE OBJECTIVES:

1. ...define the term circuit and identify examples of circuits.
2. ...distinguish between open, closed, and short circuits.
3. ...predict if the bulb will light in any given simple circuit.
4. ...identify, build, or repair a simple circuit.

EXPLORATION

Instructional materials/resources: *One battery (1.5 volts), one flashlight bulb, and one copper wire per student.*

Safety considerations: *Advise students that they should conduct experiments with electricity only with the supervision of a responsible adult. For the present lesson AC electrical outlets should be covered and/or students should be specifically advised that they are not permitted to attempt to plug anything into these receptacles without your permission.*

Instructional events:

1. Have students assigned as "getters" distribute one battery, one bulb, and one wire to each member of the class. Other students will remain at their desks or tables throughout this part of the lesson.
2. Ask students to "experiment" to determine if a bulb can be made to light using one battery and one wire. Have them work individually on this task.
3. As a teacher your role will be to facilitate student experimentation but not provide answers. Observe each student to determine if they are working and what they are doing. Use questions like the ones below to guide students who show little progress with their task.
    - What did you try?
    - What else could you try?

- Did you carefully look at the battery for clues?
- Did you find a plus and minus on the battery?
- Did you look carefully at the bulb?
- How many contacts does the bulb have?
- How could you use the wire to connect the battery and bulb?

4. As some students discover that a bulb can be made to light with one battery and one wire, ask them to draw what they see.

5. Challenge the students to try to find four ways to make a bulb light with one battery and one wire. Have them draw each way they find that works.

CONCEPT INTRODUCTION

Instructional events:

1. Make diagrams on the chalkboard of two examples each of open, closed, and short circuits. Put these in random order and do not label them.

2. At this stage in the lesson you as the teacher will be working with the class as a group. Ask students to temporarily put aside their experiments.

3. Ask students to study the diagrams on the chalkboard and predict if the bulb will or will not light in each. Have students write down their predictions and reasons for making them. Note that you have not used the word circuit in giving these directions or at any time yet during the lesson. This term will be "introduced" in step 8 below.

4. Suggest to students that they refer to their own drawings if they are having difficulties making predictions. If they remain stuck on a particular diagram they may try to build it.

5. When the predictions are complete, call on students to tell if they think the bulb will or will not light in the various diagrams on the chalkboard. Have them explain the reasons for their predictions. Use guiding questions, such as those listed below, when needed to help clarify student explanations.

   - Is the positive pole of the battery connected?
   - Is the negative pole of the battery connected?
   - Are both contacts on the bulb connected?
   - Are both ends of the wire connected?
   - Is the bulb connected so that electricity flows through it?

6. Have the students come to a consensus about whether the bulb will light in each diagram. Confirm that they are correct or suggest reasons why their predictions are in error.

7. Have the students devise a list of criteria to for predicting if a bulb will or will not light. These might include things such as the following.

   - Are the plus and minus of the battery connected?
   - Are both contacts on the bulb connected?
   - Must electricity flow through the bulb?

- Is one end of the wire connected to the battery?
- Is one end of the wire connected to the bulb?

8. Introduce the word "circuit" to the students by writing the term and its definition on the chalkboard. Tell them they have been working with three kinds of simple circuits. In a closed circuit there is a complete path for the flow of electricity and the bulb will light. Identify the diagrams on the chalkboard that represent closed circuits. Also identify and explain the characteristics of open and short circuits. In neither of these types of simple circuits will the bulb light.

CONCEPT APPLICATION

Instructional materials/resources: *Circuits Evaluation Worksheet, more batteries, bulbs, and wire, about a dozen old flashlights of various kinds.*

1. During application you will give students opportunities to demonstrate performance of lesson objectives through collaborative group work or individual efforts. As a first application activity, individual students or groups will complete a Circuits Evaluation Worksheet. This worksheet contains fourteen diagrams of circuits. For each circuit shown, the students are to predict if the bulb will light and also identify the circuit type. A performance criterion of correct prediction and identification for at least ten of the fourteen circuits may be used to establish mastery of lesson objectives #2 and #3. This will also provide evidence of development of the "scientific thinking" learning outcome that students may later include in their science portfolios. As a scoring rubric, a plus (+) may be marked on the worksheet for each diagram where a correct prediction and circuit type identification was made. A star (*) may be marked where one of only one of these was correctly done and a minus (-) may be marked on each diagram where neither was done correctly.

2. A second application activity may be to give "broken" flashlights to groups of students. These are flashlights that have been altered in several ways so they don't work. The task for each group is to repair the flashlight and explain how the repairs were made. Completing two different flashlights may be the performance criterion used to establish mastery of lesson objective #4. A scoring rubric similar to the one above can be used for assessing this application activity.

3. Groups of students may be asked to try building circuits that use more than one battery or more than one bulb. This open ended application serves as the basis for subsequent lessons on series and parallel circuits.

4. Individual students can be asked to add a "circuits" section to their science journals. With the help of their parents they are to identify and describe examples of electrical circuits they encounter over the course of a typical day. To meet performance criteria for lesson objective #1, students must identify and clearly describe at least ten different circuits that meet the definition introduced in class. Again, this will provide evidence of development of the "scientific thinking" learning outcome that students may later include in their science portfolios. A scoring rubric using a plus (+) for accurate identification and description, a star (*) for one or the other, and a minus (-) for neither may be used for assessment of this concept application assignment.

Chapter Six

Evaluation: Evaluating Students and the Effectiveness of Instruction

Subsequent to your interactions with Chapter Six, you will be expected to be able to . . .

1. ... define "evaluation."
2. ... define and distinguish between instrument "validity" and "reliability."
3. ... describe the relationships that exist between learner objectives, instruction, and evaluation. Also, be able to communicate the importance of these relationships in a classroom setting.
4. ... communicate the various purposes that evaluation can serve.
5. ... cite several forms of traditional assessment as well as nontraditional assessment and discuss both their limitations and strengths.
6. ... prepare valid examples of: (a) a matching test, (b) a sequencing task, (c) a short answer test, (d) a field/community evaluation, (e) an analysis task, (f) a science process task, and (g) an affective/attitudinal scale.
7. ... define in general terms what is meant by "portfolio assessment" and describe in some depth the variety of materials that could be incorporated into such an assessment and why they might be of value.
8. ... prepare a sound argument in support of using community resources in science or science-related instruction as well as in the evaluation of young learners (elementary and middle school).
9. ... identify (as well as discuss or defend in depth) the skills a teacher must have in order to effectively evaluate students.

Evaluation: Evaluating Students and the Effectiveness of Instruction On Understanding "Evaluation"

Evaluation Defined

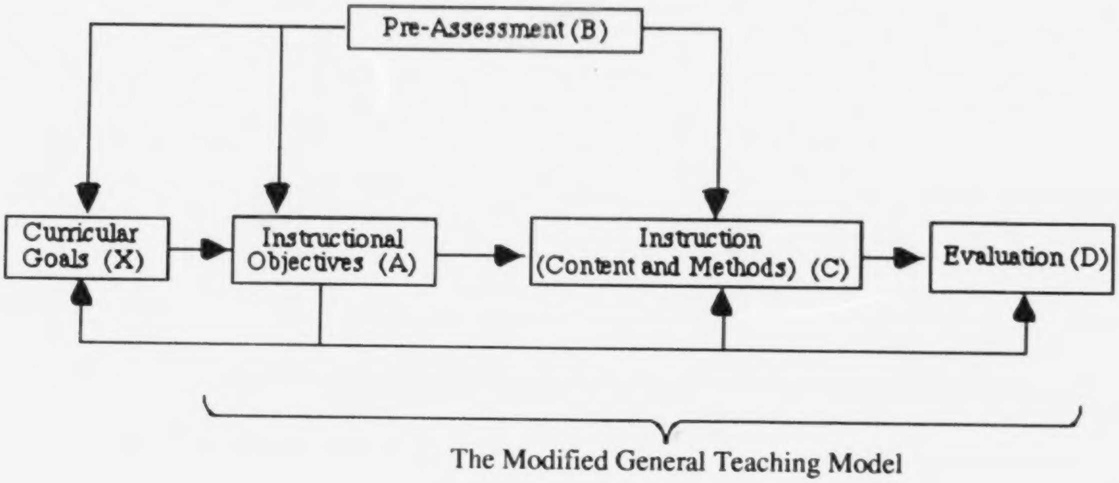
The *World Book Encyclopedia Dictionary* (1965) defines "evaluate" as follows: **1.** to find the value or the amount of; fix the value of . . . **Syn. 1**. appraise. Following this it defines "evaluation" as: **1.** an evaluating. **2.** an estimated value; valuation. Not surprising, it defines "evaluator" as: a person or thing that evaluates. If we can transpose these definitions to you and to education, we would then assume that: Acting as an evaluator, the teacher is one who must find the value of whatever is being evaluated! This rather vague statement is probably a lot truer than one might, at first, imagine. Therefore, it is probably worth reading again.

Let us take our definition a step further. Evaluation in education has a role much more critical than many imagine. It involves making critical decisions about both students and instruction. Evaluation is a process! This process is one that must be designed to obtain information which can be used to make whatever decisions are necessary: How well did the student(s) do? Did the students accomplish the objectives of the lesson . . . unit . . . module . . . chapter? Have the students reached established curricular goals? Should the curriculum be modified? Was my instruction effective . . . successful? What modifications of instruction, if any, need to be made? Am I doing the job expected of me by myself and others? Critical decisions all!

Where Does Evaluation Fit?

Interestingly, evaluation is part and parcel of instruction! The diagram of the General Teaching Model presented below, is an excellent illustration of the relationships that exist within the overall act of instruction and curriculum. You have become familiar with the General Teaching Model in the previous chapter, and you already know that instruction involves the development of objectives, pretesting where needed, direct

The General Teaching Model


Pre-Assessment (B)
Curricular Goals (X)
Instructional Objectives (A)
Instruction (Content and Methods) (C)
Evaluation (D)
The Modified General Teaching Model

instruction, and evaluation. The interconnectedness of all of these parts should be obvious. As are well aware, it is critical to make certain that there is consistency between evaluation, instruction, and the learner objectives. In simple terms, you should identify what you want students to know or do; you should provide instruction which will enable them to know or do those things which you identified; and you should evaluate in a manner which will allow you to determine if your students know or can do what you identified and taught them to do. Although that seems very simple and straightforward, many of our educational efforts appear to lack the consistency which this model considers critical to learning.

Two Major Concerns in Evaluation: Validity and Reliability

Validity

Validity is related to an educational syndrome called "apples and oranges." Far too often, in instruction, we teach "apples" and evaluate "oranges". Let's return for a moment to the General Teaching Model. If we prepare learner objectives that focus on the development of critical thinking skills and then evaluate students over the concepts they have learned instead of over those thinking skills, we have entered the world of "apples and oranges" (i.e., "teaching for apples and evaluating oranges"). The consistency that is so desperately needed in the instructional model has been violated. We suspect that 100% of the readers of this methods book can cite examples of professors who have given out objectives to be mastered, only to evaluate over some other unknown set of objectives or agendas. Unfortunately, this phenomenon is entirely too prevalent in today's educational climate.

Validity has to do with "hitting the mark" in evaluation. It is something like bowling. You want the ball to hit the pocket in order to get a strike when you bowl. Anything less is likely to leave pins standing. You want to "hit the pocket and get a strike" when you evaluate students.

When you plan an evaluation it is important to reflect on the evaluation scheme and to determine whether the scheme appears to evaluate what you intend to evaluate. When you do this you are inspecting something called "face validity." If, on the face of it, the scheme appears to be appropriate, you have achieved face validity. This is an important, albeit not a very scientific analysis. Another kind of validity is something called "content validity." Content validity is a bit more scientific. Here you actually inspect the evaluation scheme and compare it against content that was covered during instruction (e.g., skills, concepts, attitudes taught for). If, again, you observe the "apples and oranges" phenomenon, you have missed the mark with the evaluation. Content validity can also be measured by people other than those that developed the evaluation. This is often done for research purposes - getting a peer appraisal of the evaluation scheme or instrument. If the peer evaluation states that the analysis shows consistency between the scheme/instrument and what is being taught, content validity can be assumed.

Validity assures that you evaluate what you intend to evaluate!

Reliability

Reliability can be a bit trickier! Reliability asks that whatever means of evaluation is used that it evaluate the same over time. Sounds confusing? Yes, it can be a little! Let us assume that you are married with a small child. You and your spouse want to go out once in awhile without the young one. You need to hire a baby sitter. You want someone who will do a good job when sitting. However, you also want someone you can count on over time. You want to locate someone who is "reliable" (i.e., consistent, stable, predictable, and dependable). This is what is meant by "reliability"! Let's go back to our bowling example but look at it a bit differently. You want to be able to hit the pocket over and over! You want to be a consistent bowler - perhaps not a 300 average bowler but as close to a 300 average as possible. The closer you can get the more "reliable" you are - bowling close to 300 over and over and over! This is what you would want to look for in evaluation as well. How about an educational example? Measuring the development of science process skills in learners is important in science education. Assume that you have an instrument for the measurement of science process achievement. You want to focus on the development of process skills for an entire year. You decide to give the instrument to your students four times: (1) as a pretest, (2) midway through the first semester, (3) midway through the second semester, and (4) at the end of the year. If your instrument is valid and your instruction is on target, the results should show improvement at each testing. If the test scores for your students are orderly and consistently improving, the test is probably reliable. It is demonstrating consistency over time. If the scores appear to be chaotic either the instrument is not reliable or your instruction is not getting the job done!

Reliability assures that you evaluate in a consistent manner over time.

Traditional and Nontraditional Evaluation

Remember, evaluation is a *process* that is designed to *obtain information* which can be used *to make whatever educational decisions are necessary.* Some of those decisions? How well did the student(s) do? Did the students accomplish the objectives of the lesson . . . unit . . . module . . . chapter? Have the students reached established curricular goals? Should the curriculum be modified? Was my instruction effective? . . .

Was it successful? What modifications of instruction, if any, need to be made? Am I doing the job expected of me by myself and others? Critical decisions all!

Evaluation as seen by many educators!

An Introduction to Both Traditional and Nontraditional Forms of Assessment

All of us in education are familiar with many of the traditional forms of evaluation. Who has not experienced many of the forms of "paper and pencil" evaluations (e.g., multiple choice, fill in the blanks, matching, short answer, "long answer", term papers, and true and false)? Currently, the phrase "forced choice response" is being used to describe these kinds of assessment items. Who among us has not wondered of the value of at least some of our evaluation experiences, questioning the validity of same? Nonetheless, many instruments used in our pasts have undoubtedly been valid and the results were often used to grade our work.

Fear not! These paper and pencil evaluations are still with us and will probably remain with us for some time to come. Examples of some of the better ones will be found later in this chapter.

Currently, in education, we are beginning to also see a major interest in nontraditional forms of evaluation (i.e., called alternative assessment). A vast majority of the states in the U.S. have begun demanding some form of alternative assessment. Maryland, Missouri, Hawaii and New York are examples of these. These alternative assessments range dramatically in scope from written tasks, such as reporting an original science investigation, to performance tasks, such as accomplishing a service activity in the community related to science or the environment. These two examples are not figments of one's imagination! They are tasks being assigned to students in some states in the U.S. In fact, in some states a high school student cannot graduate without successfully completing some of the alternative assessments demanded by various state departments of education.

Dr. Tom Marcinkowski of the Florida Institute of Technology has developed a framework which identifies three general contexts in which assessments are conducted (1993). These three are:

- **Natural Activity, Natural Setting:** A student's performance is observed in the course of her or his everyday activity.
- **Structured Activity, Natural Setting:** A student is presented with an assignment by the teacher; her or his performance in carrying out that assignment is observed.
- **Structured Activity, Structured Setting:** A student is presented with a task to complete in a test-like setting; her or his performance in carrying out that task is observed.

These contexts indicate that evaluation can take place in or out of school using normal everyday activities somehow related to the educational process or structured activities prepared for the student by the teacher. The phrase "complex generated response" is being used to describe the kinds of assessment tasks that may arise in the settings described above.

Given the interest currently in both traditional and nontraditional forms of assessment, the following sections of this chapter take on new meaning. What follows is an effort to categorize some of the traditional and nontraditional forms of assessment and provide examples from the literature. Keep in mind that these are examples that students are actually doing in parts of the U.S.

Evaluating Knowledge: A Variety of Strategies

Example No. 1:
The Very Traditional Multiple Choice Instrument

Valid and reliable multiple choice tests are not easy to construct. What follows are examples of items taken from an instrument developed by Dr. R. Champeau, et al. and the Wisconsin Environmental Literacy Assessment Project. These items test a student's knowledge of ecological concepts. Students circle the best response for each item.

3. Which of the following is a predator-prey relationship?

   a. A flea bites a dog.
   b. A robin eats a worm.
   c. A caterpillar eats a leaf.
   d. A deer eats grass that has a grasshopper in it.

4. A fox dies. This creates a problem for:

   a. the fleas that were drinking the fox's blood.
   b. a rabbit that has a nest nearby.
   c. another fox whose territory is nearby.
   d. an animal that hunts in the same area that the fox did.

5. Termites eat only wood. However, they cannot digest it. Tiny organisms that live in termites' stomachs and intestines digest the wood. The relationship the tiny organisms and the termites have is:

   a. helpful to one and has no effect on the other.
   b. helpful to one and harmful to the other.
   c. helpful to both of them.
   d. helpful to neither of them.

Example No. 2:
The Matching Test

Matching can be an effective tool when the student must be able to demonstrate an understanding of the differences between important items and components of those items. For example, if a teacher feels it important for students to be able to conceptualize a variety of ecosystems in some depth as well as the plant communities found in those ecosystems, the following might be useful:

What follows is a matching task. You will find important ecosystems listed to your left. With each is a blank. On the right you will notice common plant types. You are to write the letter of each plant in the blank next to the ecosystem in which it is typically found.

1. Sonoran Desert _____
2. A Midwestern Marsh _____
3. A Tropical Swamp _____
4. A Tall Grass Prairie _____
5. A Midwestern Deciduous Forest _____
6. Canadian Tundra _____
7. Coniferous Forest _____

a. Northern Spruce
b. Skunk Cabbage
c. Strangler Fig
d. Big Bluestem
e. Ocotillo
f. White Oak
g. Reindeer Moss

You say you want the answers? Just this once! 1=e; 2=b; 3=c; 4=d; 5=f; 6=g; 7=a.

Example No. 3:
An Identification (Listing) Task

At times it is important to know the extent to which a student can identify items from a wide array of alternatives. In the assessment that follows, the student is asked to identify environmental issues. However, it is not quite that simple. He/she is also asked to write the issues in such a manner as to allow the evaluator to determine if the student has a concept of cause and effect with respect to the issue. A part of the assessment follows [adapted from an environmental literacy instrument being developed at SIU-C by H. R. Hungerford, T. L. Volk, and W. J. Bluhm (1994)]:

Directions: Below, you are asked to **list up to ten (10) environmental issues** with which you are **currently familiar**. The example shows you the way to write items for your own list. It is important to include both **the cause** and **the effect** in your issues. In the example, **the cause is habitat destruction**. The **effect is what happens to wildlife in Maryland**.

My list of environmental issues with which I am familiar:

Example: *The effect of habitat destruction on wildlife mortality in Maryland.*

1. ______________________________
2. ______________________________
3. ______________________________

Example No. 4:
The Short Answer Evaluation

Many times it is appropriate to ask questions or pose situations that demand writing tasks from the students. It is important that the questions/tasks themselves be valid! Also, these items can be very difficult to evaluate. Many are the times when the teacher will prepare a short answer evaluation and find, much to his/her frustration that they are not easy to evaluate. Two examples follow:

1. Louis Pasteur was forced by circumstances to test his rabies vaccine long before he planned to do so. Describe the circumstances and the outcome.

2. The fragmentation of North American forests is thought to be a major reason for the decline of migratory song birds. Please explain why this is the case and provide at least three examples of song bird species that would be involved.

Example No. 5: Listing in Proper Sequence

There are times when listing in a random order simply will not suffice. Sometimes a sequencing of knowledge is called for. Two examples follow [No. 2 is modified from a science process test developed and used at SIU-C].

No. 1. Insects with a complete metamorphosis have four stages to their life cycles. Beginning with any stage, list the four stages in order:

a. ____________________

b. ____________________

c. ____________________

d. ____________________

No. 2. Scientific problem-solving usually involves the use of a number of skills. Below are listed some of those skills. However, the sequence in which they are listed is incorrect. You are asked to reorganize the list so that the sequence (or order) is correct. Place a 1 next to the process that would be first. A 2 will be written next to the process that would be the second one used. A 3 will be written next tot he process that would be used third, and so on until all six are in the proper sequence.

A. _____ A hypothesis is written by the investigator.

B. _____ The investigator observes an event that does not appear to be consistent with what is known by him about some aspect of the universe.

C. _____ The investigator chooses an experimental design with which he/she can conduct the investigation.

D. _____ The investigator interprets the data.

E. _____ Data are collected and recorded.

F. _____ A decision about the validity of the hypothesis is made.

Example No. 6: Making Field Observations - A Structured Activity in a Natural Setting

If education should be designed to help students learn how to be effective members of their communities, it appears logical that some of their experiences as well as evaluations should be conducted outside of the classroom walls. What follows is a portion of a natural setting evaluation that has been used for over a decade at SIU-C and in middle and secondary schools across the nation [a number of items have been removed in order to conserve space]. This particular assessment follows a unit on ecology and is designated to have students go out into a natural ecosystem and apply what has been learned in the classroom in a natural setting.

Observing A Living Ecosystem

Procedures:

You are being taken to an ecosystem that seems to be typical of the one that exists in the region where you live. It is a terrestrial environment. Walk into it an spend some time observing the things around you. Don't worry too much about the names of things in the ecosystem. Instead, try to observe it from a number of different perspectives. The questions which follow will help you focus your observations to the best of your ability. Note, however, that this assessment will take more than a few minutes to complete.

1. What would you call this living system? Is it a hardwood forest? A vacant lot? A prairie? A desert? Just what is it you are observing?

2. Do you believe that this environment is dominant in the region in which you live? In other words, is this an extensive living system in the region?
Yes _____ No_____ Provide your reasons for answering as you did.

3. What are the general characteristics you see when you observe the overall character of this system? If a drawing would help supplement your description, feel free to make one.

4. What are the nonliving (abiotic) factors that seem to be controlling the character of this system? For example, what might be the influence of topography? Bed rock? Humidity? Rainfall? Air temperature? Soil temperature? Insolation? Etc.? Now how do these abiotic factors appear to be controlling the character of this living system?

5. What populations of plant and/or animals can you observe here? What is your evidence?

6. What evidence exists, if any, to indicate that food energy flows through the system? If you want to diagram your evidence, please do so.

Example No. 7: The Compound Multiple Choice Item Combined with Short Answer

Many times in a science course, there comes a need or desire to evaluate students on a number of "items" simultaneously. This kind of an evaluation can also incorporate a short answer mode or not, depending on the course objectives. The following evaluation is an example of one that might find use in a lengthy science-technology-society unit:

1. Below, you will find a list of names of famous people, either scientists or technologists (or a definite combination of both) or none of these. In the blank following the name, you will identify that person as a scientist (S) or a technologist (T) or a combination of both (B) or none of these (N). Then, you will answer No. 2 which is closely related.

1. Louis Pasteur _____
2. Joseph Lister _____
3. Thomas A. Edison _____
4. Mickey Mouse _____
5. Edward Jenner _____
6. Chas. Darwin _____
7. John James Audubon _____
8. William Harvey _____
9. Alexander Fleming _____
10. Linus Pauling _____
11. Anton Von Leeuwenhoek _____
12. Stewart L. Udall _____
13. Rachel Carson _____
14. Jane Goodall _____
15. A. Graham Bell _____
16. Robert Fulton _____
17. Henry Ford _____
18. Eli Whitney _____
19. Goofy _____
20. Joseph Priestly _____

2. From the list of twenty names, choose two (2) that you identified as "technologists" or as a "combination" of scientist and technologist. Identify each and write a short paragraph defending your selection. Be sure to provide very specific reasons for your identification.

Example 8:
Analysis Tasks -
A Structured Activity in a Structured Setting

A student's ability to analyze something is usually thought to be a more powerful intellectual attribute than his/her ability to respond correctly to knowledge or comprehension tasks. What follows is one example of a compound analysis task. The student reads an anecdote and responds to that anecdote in a number of different ways. You must assume that the student has been taught the skills that are asked for in this assessment. However, you can also assume that the student has never seen this particular anecdote before. Thus, it is an excellent example of an analysis task, albeit a complex one.

AN ISSUE ANALYSIS EVALUATION

The Story: A QUESTION OF PROGRESS

Recently the medium size midwestern city of Ironton experienced a problem that dealt with a serious land-use management question. A developer approached Mr. Henry Tillman and offered to purchase eighty (80) acres of his farm in order to build a new shopping mall.

Mr. Tillman's farm was the first one next to the city limits. It offered an ideal location for a shopping center. The developer, Mr. Hank Smith, explained that he would be willing to pay up to one million dollars ($1,000,000) for the field. Mr. Tillman knew that the field was worth about $50,000 on the open market as agricultural land. He decided to sell if the zoning regulations could be changed.

Getting an option on the land, Mr. Smith went to the Zoning Commission and requested that the zoning restriction be changed from "Agricultural" to "Commercial." He explained that the mall would bring millions of dollars to Ironton and would encourage additional commercial development on that side of town. In addition, he told the commission that dozens of jobs would be created. The commission agreed to study his request and act on it at its next regular meeting.

The ***Ironton Daily News*** published Mr. Smith's request the very next day and reactions were immediate. Several groups took exception to the proposed change in zoning. Others supported the development of the mall.

The information above contains an environmental issue. Please name the exact issue that exists in that information. Do this in one sentence.

Issue: ____

____

The county agricultural association took exception to this use of the land, commenting that the area was losing far too much agricultural land to commercial and residential development. The Chamber of Commerce was pleased, citing continued development for the city. The local builders' union was also pleased and supported the rezoning of the land. The union knew the value of construction jobs for its members.

Residents on the side of town on which the mall would be located argued against the development, citing traffic congestion, increased crime, lack of privacy, and a number of other things which would be negative for family living. Members of the local Sierra Club were very disturbed because a rare natural area was close to Mr. Tillman's farm and additional development could jeopardize the well-being of this area.

Mr. Tillman was interviewed by the ***Ironton Daily News*** and he told the reporter that the money would be great for his retirement. He also said that he should be able to sell his land to anyone he chose because it was his and he could do whatever he pleased with it.

There is an environmental issue here. A problem exists and it has become an issue. There are numerous "players" and all of the players have beliefs and values operating. Below, you will find a list of key players. For each player, you are to identify that player's belief and the most important value present in that belief. Some players may have communicated more than one belief.

PLAYER	THE PLAYER'S BELIEF	THE VALUE
Mr. Smith		
Mr. Tillman (2)		
County Ag. Assn.		
Chamber of Comm.		
Builders' Union		
Local Residents		
Sierra Club		

Issue Information Continued:

One month after the initial proposal, the Zoning Commission decided to change the zoning on the land from "Agricultural" to "Business." Thus, the stage was set for the mall to be developed. Needless to say, some people were happy and some were unhappy. As soon as the Zoning Commission acted, the Sierra Club asked the County Judge for an injunction to prohibit the change in zoning. The Sierra Club argued that the shopping mall would, indeed, endanger the rare natural area close to Mr. Tillman's farm and that the Zoning Commission had not taken this into consideration in making its decision.

Let us assume that the judge denied the injunction requested by the Sierra Club. This action opens the way for the mall to be built. There would, of course, be consequences. Below, describe the consequences of this action for each of the following categories:

Economic Consequences: ____________________

____

Ecological/Environmental Consequences: ____________________

____

Scientific processes involve many different intellectual attributes. These can be assigned names such as those found in Bloom's Taxonomy (e.g., analysis, synthesis, evaluation). Others can be named according to the scientific process involved (e.g., observing, hypothesizing, predicting, measuring, experimenting). Example No. 9 involves hypothesizing and experimenting. As you did with Example No. 8, you must assume that the learner has been trained in these processes.

Example No. 9: A Process Task Involving the Design of a Simple Experiment

You and your lab partner have been given a large rubber band that has been cut into one long piece. You have also been given a meter stick to use as a measuring device. One of you should stretch the rubber band so that it is 50 centimeters in length. The other member of the team should pluck the rubber band. Both of you should listen very carefully and observe the pitch of the sound.

A. Hypothesize what the pitch would sound like if the rubber band was stretched further. Stretched less. Write out your hypotheses below:

Hypothesis No. 1: Rubber band stretched more.

Hypotheses No. 2: Rubber band stretched less.

B Design an experiment to test your hypotheses. Briefly describe this experiment below.

C. Conduct the experiment. Record the results.

D. Do you accept or reject Hypothesis No. 1?

E. Do you accept or reject Hypothesis No. 2?

Example No. 10:
A Community Science-Technology-Society (STS) Issue Investigation - The Use of a Checklist and a Contract

The higher order thinking skills of synthesis and evaluation are not easily taught. In addition, evaluating the extent to which these processes have been acquired is not easy either. Still, there isn't a single school district that would not advocate teaching higher order thinking skills such as these. Example No. 10 is an example of one proven semester-long strategy for teaching and evaluating these skills. But first, let's set the scene for you.

The curriculum with which this particular evaluation mode will be used is a one semester program designed to teach middle and secondary students (grades 5-12) STS issue investigation and application skills (i.e., teach the skills and then send students into the community to do an actual, in-depth issue investigation). Once the skills have been taught and the major investigation assignment given, the teacher "evaluates" the step by step processes involved in preparing for and conducting the investigation. This is done via the "Investigation Task Checklist," found below. This checklist keeps track of each student's investigation and is a wonderful way of checking the progress of each student in class.

Investigation Task Checklist

Investigation Task	Due Date	Teacher's Approval
1. Selection of issue topic	________	________________
2. Completion of secondary source search	________	________________
3. Approval of research questions	________	________________
4. Approval of letters for information	________	________________
5. Approval of interview questions/format	________	________________
6. Approval of data collection plan	________	________________
7. Approval of instrument	________	________________
8. Approval of data collection	________	________________
9. Approval of charts, tables, graphs	________	________________
10. Approval of conclusions, inferences, and recommendations	________	________________
11. ________________________	________	________________

The actual issue investigation is conducted and evaluated via the use of an "Issue Investigation Contract", found below. The **contract** is an opportunity for student and teacher to agree on the responsibilities and rewards of effective, independent work. With the use of the contract, the student knows up front what the evaluation elements will be and how much weight each element carries. The contract also signifies an agreement between student and teacher to complete a major assignment (i.e., the STS issue investigation). The contract is signed by the student, the teacher, and a witness. Usually another student acts as the witness but another teacher or a parent could, as well.

THE STS ISSUE INVESTIGATION CONTRACT

Student: ______________________________ Teacher: ____________

Name of Issue Investigation: ______________________________________

____

I hereby contract with my instructor that I shall use all my mental ability and those skills in which I have been trained in order to successfully investigate the issue chosen. Further, I guarantee that my independent investigation will be conducted in a manner as to give me pride in myself and to respect the rights of other human beings. I understand that my research will be evaluated on a raw-score basis and that my final grade for this project will be based on the number of points earned. Further, I have read the following breakdown of criteria and understand how I will be evaluated.

Criteria	Possible Points	Earned Points
Quality of the research question(s)	______	______
Techniques used in the investigation	______	______
Seriousness of approach to research	______	______
Quality of data collected	______	______
Accuracy of conclusions	______	______
Quality of inferences	______	______
Accuracy and organization of final report	______	______
Class presentation	______	______
Other ______________________	______	______
Grand Total	______	______

______________________________ ______________________________
Signature of Student Signature of Teacher

______________________________ ______________________________
Signature of Witness Date

Evaluating Attitudes and Related Topics

Is it OK for a teacher to have an attitude problem? Probably not! However, it might not be a good idea to ask this one with reams and reams of papers to grade. Every teacher feels like this every so often.

Attitudes and other affective attributes are difficult to evaluate. Likewise, the teacher must be very careful about the use of such assessments. Seldom are attitudes used as a part of the grading process. As educators, we can demand certain knowledge from our students and certain skills but to what extent can we demand that the students delight in what they are doing in the classroom?

We usually frown on using affective evaluations for grading purposes. Because of this, the assessment of attitudes may well be more useful for evaluating the effectiveness of instruction or of our teaching methods than evaluating the learners as such.

What are some affective attributes that might be profitable to evaluate? Consider the importance of whether or not the learner is, indeed, content with the science education experience. Also consider how the student feels about the content of the unit(s) being experienced, the teaching methods, the laboratory experiences, the tests, the teacher, his/her peer interactions during science class, etc.

There are a number of strategies available for assessing affective attributes. A few examples of these strategies follow.

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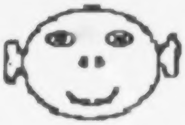
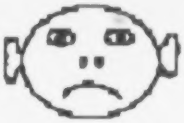
Example No. 11:
A Simple Strategy for Use With Young Learners

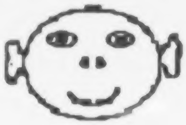
An effective strategy for use with young learners uses the "happy face/sad face" technique. Here the teacher would have the students draw a circle around the face that best showed how they felt about certain variables. Students could also be asked to make an "X" through the face that best showed how they felt. You will find a few examples on the next page:

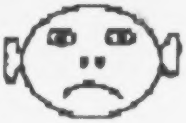
1. How did you feel about the lesson on dinosaurs?



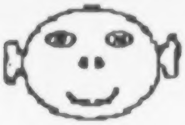


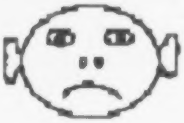
2. How do you feel about your teacher?



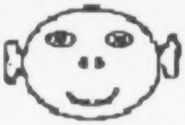


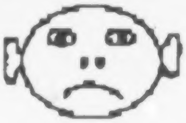
3. How did you like the field trip to the museum?





4. Would you like to learn about how plants and animals live in the jungle?





Hi gang! Let's get started on our evaluation! There are lots of neat things that we can do to show how well we know things, how well we can do things, and how much we enjoy being in school. It's lots of fun!

Well . . . maybe! He might get an argument from many students on evaluation being fun. Yet, it can be exciting and drastically different from the traditional ways of doing things.

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Example No. 12:
Forcing Their Choices

At times it is really important to assess certain attitudes (or perceptions) held by learners. In this example, the assessment will tell the teacher which environmental issues the students believe to be the most important. It will also help the teacher determine the thrust of instruction, particularly if he/she knows that student perceptions are inaccurate.

Here the student is asked to select, from the list provided, the three most important environmental issues facing human beings today. The student will write a "1" in the blank next to the one thought to be the most important, a "2" for the one thought to be the second most important, and a "3" in the one thought to be the third most important. The student is not permitted to select any as being equally important. It is a forced choice situation.

The Issues

_____ Human Overpopulation
_____ Endangered Species
_____ Global Warming
_____ Ozone Depletion
_____ Food Production
_____ Food Distribution
_____ Land-Use Management
_____ Water Pollution
_____ Air Pollution
_____ Noise Pollution
_____ Aesthetic Pollution
_____ Sewage Disposal
_____ Solid Waste Mgmt.
_____ Wildlife Management
_____ Fisheries Management
_____ Energy Conservation
_____ Nuclear Power
_____ Toxic Waste Disposal
_____ Environmental Health
_____ Deforestation

Example No. 13: The Likert Scale:
A Strategy for Older Learners - One With Great Potential

The Likert Scale can take more than one form. Here we will use a five point scale ranging from "No Extent" to "A Great Extent" responses (see the example on the following page). Again, the teacher can use the results of these kinds of assessments to judge the affective posture of the learner, the attitude of the learner toward the instructor, the attitude of the learner toward the overall science experience, whether or not instruction has been successful from an affective point of view, and how upcoming instruction should be structured.

The examples which are found on the next page are not designed to serve as an overall evaluation. The items are simply examples of situations that might be posed to learners covering a wide array of variables. Learners are asked to circle the "X" that best reflects how they feel about a particular item.

Directions: These questions are designed to discover how you feel about a wide range of things. Please read each question, think about it carefully, and then circle the "X" that best communicates your feelings.

1. To what extent do you think that you are "environmentally sensitive"? This means that you care about and feel a sense of concern for the environment.

X X X X X

No Extent A Moderate Extent A Great Extent

2. To what extent do you feel that women can make excellent scientists?

X X X X X

No Extent A Moderate Extent A Great Extent

3. To what extent do you believe that smoking (or other uses of tobacco) is harmful to your health?

X X X X X

No Extent A Moderate Extent A Great Extent

4. To what extent do you feel comfortable with the science course in which you are now enrolled?

X X X X X

No Extent A Moderate Extent A Great Extent

5. To what extent do you like the cooperative group work that is assigned to you in the science classroom?

X X X X X

No Extent A Moderate Extent A Great Extent

Example No. 14:
Another Rating Scale That Has Promise

Another scale uses the agree - disagree mode. Here the scale runs from "Strongly Agree" to "Strongly Disagree." It works much like the Likert Scale introduced in Example No. 13.

Directions: This activity is designed to find out how you feel about a wide range of topics. Please read each statement, think about it carefully, and then circle the "X" that best communicates your feelings.

1. Every licensed driver should be made to use seat belts.
Strongly Agree Agree Neutral Disagree Strongly Disagree

2. My classmates never try to cheat on tests in science.
Strongly Agree Agree Neutral Disagree Strongly Disagree

3. My science teacher is wonderful.
Strongly Agree Agree Neutral Disagree Strongly Disagree

4. I have been thinking about a career in some aspect of science or technology.
Strongly Agree Agree Neutral Disagree Strongly Disagree

5. I think that it is OK to shoot ducks and geese out of season.
Strongly Agree Agree Neutral Disagree Strongly Disagree

Example No. 15:
The Comparative Rating Scale

Sometimes the use of what we will call "The Comparative Rating Scale" is useful. It uses a scale between "Of No Importance" and "Of Extreme Importance" and forces the student to choose between them along a scale, often a ten point scale. The student can choose to mark close to one end or the other or right in the middle. It indicates to the evaluator the attitude(s) held toward the variable in question. Here are examples heavily adapted from Dr. Tom Marcinkowski (in: Richard J. Wilke, Editor, *Environmental Education Teacher Resource Handbook*, Millwood, New York: Kraus International Publications, 1993, p. 182).

Of No Importance Of Extreme Importance

1. A world of beauty ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
2. Scientific research ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
3. Technology ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
4. The space program ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
5. Medical research ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
6. Tropical rain forests ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
7. Women in science ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
8. Biodiversity ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Using Portfolios for Assessment

A portfolio is a collection of student selected materials assembled to represent learning over time.

A portfolio is a collection of student selected materials assembled to represent learning over time. By examining a portfolio a teacher may assess ways in a which a student has been involved in the processes of instruction (e.g., cooperative group work, journal writing). The teacher may also assess the quality of the performances or products that are a result of instruction. A portfolio represents a student's perspective throughout, continuously reflecting their emerging knowledge, skills, and attitudes.

It is important that a portfolio contain the element of student reflection. Evidence of the development of "big ideas" over time, the use of higher order thinking skills or the integration of science with other fundamental areas of learning constitute student reflection. Items such as journal entries, project or experiment reports, posters, sketches, video tapes, computer based productions, graphs, models, collaborative group projects or special collections might be selected by a student as part of a science portfolio. Such complex generated responses require the student both recognize and process, or reflect upon, their learning.

A portfolio represents a student's perspective, reflecting his or her emerging knowledge, skills, and attitudes.

The specific purposes and format of a portfolio are determined in advance with the teacher's guidance. The criteria for student inclusion of materials and the criteria for assessment of the portfolio are also defined in advance. Typically these criteria require that the selected materials match instructional objectives, reflect different types of learning, and show performance in different contexts over time. Portfolios may be used to document work in progress or to represent what has been accomplished by a student during a semester or year. Similar, portfolios may be used to showcase student development and progress within a grade, or from grade level to grade level.

The physical structure of a portfolio may go well beyond a file folder. Given the variety of assessment items mentioned above, a portfolio may be contained in a three ring binder, hanging file folders, storage boxes, or stacking plastic cartons. Recently electronic portfolios have become not only possible, but also commercially available.

Portfolios represent a way of teaching. They encourage a classroom where assessment is a continuous part of instruction. In using portfolios, teachers and students interact frequently about both the processes and the products of instruction. Students come to see learning as a long term event with many aspects. Teachers attend to learning that occurs in different domains as the focus of evaluation shifts from forced choice to complex generated response assessment. Both teachers and students stay focused on instructional goals or learning outcomes. Teachers communicate about student progress in specific knowledge and skill areas among themselves as first grade teachers pass portfolios to second grade teachers and so on. Teachers are able to establish a dialogue with parents by discussing real examples of student work and long term development learning. Authentic instruction as well as authentic assessment takes place in a portfolio based classroom. Is this your way of teaching or do you prefer students quietly seated in rows with paper and pencil in hand? While the choice about how you teach is yours the consequences of that choice fall to your students.

What Does the Teacher Need to Know and Do?

There are a number of "conditions" associated with valid and reliable assessments. Being able to adequately evaluate both students and instruction does not happen as if by magic. There are guidelines and some skills that need attention. Among them are the following.

1. an ability to design, prepare, and select assessments that are consistent with the student objectives and instruction. You will recall a brief discussion about this in relation to the General Teaching Model earlier in this chapter. The ability to come up with evaluation instruments that are totally consistent with what is happening during instruction is crucial. This also implies that the teacher is able to judge the validity of an assessment (or know how to get the validity judged by using an external validity panel). Likewise, the reliability of the assessment must be carefully considered and respected.

2. an ability to teach for and carefully evaluate higher-order thinking skills (e.g., synthesis and evaluation). The authors have been very careful to present examples of this kind of evaluation in this chapter. However, it is important to note that these skills are not easily come by but are critical to successful teaching, particularly at the middle school level and beyond.

3. an ability to place students in the real world (outside the classroom) for substantial parts of their education and an ability to evaluate their success in community-based learning experiences.

4. an ability to prepare for and use alternative assessment strategies (e.g., the portfolio assessment strategy). A certain amount of intelligent creativity should go into the selection and use of alternative assessments. The student should understand that he/she is partially responsible for the development and maintenance of evaluation records. Further, the school should allow for the incorporation of very personal evaluative items to be incorporated (e.g., a letter from a community official commending the student for civic service, a special award from an organization, as well as blue ribbons, medals, or certificates won in county fair competition or photographic competitions, etc).

Chapter 7

Models for Action—Hands On Science Programs

Subsequent to your interaction with Chapter Seven, you will be expected to be able to …

1. … identify and discuss the distinctive features of SCIIS and FOSS as specified by your reading assignments and your instructor. Similarly, you will be able to identify and discuss these programs' physical and educational characteristics (as well as any limitations) as specified by your instructor.

2. … briefly discuss the development of the SCIIS and FOSS curricula, including place of origin, funding agency, involvement of schools in the processes and commercial dissemination.

3. … state correctly the overall objective of SCIIS as specified in your readings. Include in your response the scientific literacy component as well as relating the component to knowledge, skills, and attitudes.

4. … describe how the content of SCIIS reflects a conceptual hierarchy.

5. … cite evidence to support the contention that the entire SCIIS program relates to an overall concept of "interaction."

6. … defend the position that the knowledge component of SCIIS has great merit from a general education perspective.

7. … state correctly the overall objective of FOSS as specified in your readings. Include in your response the scientific literacy component as well as relating the component to knowledge, skills, and attitudes.

8. … explain what is meant by instructional efficiency and describe how this is achieved by the FOSS program.

9. … explain how the structure of FOSS is designed to correlate with the stages of cognitive development of elementary school students.

10. … describe how collaborative groups are used in the FOSS program. Contrast the grouping methods used for early and upper elementary grades.

11. … accurately compare SCIIS and FOSS in all of the following dimensions:

    a. goals and objectives.
    b. scope and sequence.
    c. interdisciplinary features.
    d. physical components such as kits and manuals.
    e. organization and format of lessons.
    f. hands-on experiences for students.
    g. reading and writing opportunities for students.

h. provisions for involving special populations of students.
i. materials provided specifically for the teacher.
j. instructional technologies and how they are incorporated.
k. student assessment techniques.

12. ... defend the position that, although the SCIIS and FOSS programs differ, both reflect an inductive approach to learning.

A COMPARISON OF TRADITIONAL AND HANDS-ON SCIENCE METHODS

TRADITIONAL SCIENCE METHODS	HANDS-ON SCIENCE METHODS
STUDENTS: . . .	*STUDENTS*: . . .
• **Read And Memorize** - information about science	• **Participate In** -the science enterprise
• **And Do** - cookbook lab exercises	
• **Which Reflect** - little motivation	• **With** - high motivation
• **In Order To** - please the teacher - gain a good grade	• **Because They Are** - doing science
• **Which Results In** - poor retention - little transfer - fewer cognitive skills - failure for many	• **Which Results In** - inductive learning - critical thinking skills (processes) - long term retention - transfer potential - success for many
• **And Develop The Attitude That** - science is boring	• **And Develop The Attitude That** - science is important and interesting - school can be an exciting place to be
• **And Experience** - a poor educational technology	• **And Experience** - an improving educational technology

Models for Action—Modern Science Programs

Introduction

Although tens of thousands of elementary school students still experience either no science at all in their classrooms or "read about science" programs, a number of "hands-on" activity -based, sophisticated science programs exist. These modern science programs have been developed over the past several decades with substantial grants of money from both private and federal sources.

Although these science programs reflect somewhat differing emphases, they have some significant common attributes. All are inquiry oriented (i.e., students DO science and INDUCTIVELY generate knowledge). All permit a wide range of students to experience success in science. All de-emphasize the traditional relationship between reading ability and achievement (i.e., students experience almost no reading at all or a minimal amount). All have been trial tested by using them with students. Further, trial testing in schools across the nation resulted in revisions of materials before being commercially produced.

All of the modern programs demand special training for teachers in order to be maximally effective. Although many educators seem to constantly search for panaceas or their own private instructional Valhallas, these are not likely to be found in modern science programs. Any program is only as good as the teacher using it! The modern programs demand, besides training, dedication and hard work on the part of the classroom teacher. They also demand the support of the administration and the community. The school board must be willing to financially support the acquisition and implementation of the program as well as allocate teacher preparation and planning time.

Even though significant problems can arise in the implementation of modern science programs, they are highly recommended. With these programs, teachers have available science materials which substantially narrow the gap between what is offered the students and their ability to function intellectually. These programs have the ability to help transform educational lip service concerning scientific literacy into action and the subsequent reality of intellectually competent human beings.

In this section, we will deal with two popular hands-on science programs. Sufficient background information and experiences will be provided to permit the acquisition of functional concepts concerning each. These experiences do not guarantee that you will become an expert in either of these programs. However, you will acquire realistic and functional perspectives concerning these programs from both teacher and student standpoints.

Finally, the authors realize that you may not teach in a school which has adopted one of these programs. Unfortunately, results from a recent survey of elementary science programs across the U.S. indicate that fewer than 10% of U.S. elementary schools use these programs. Then, "Why study them?" you may ask. The reason rests in the title of this section—Models for Action. Examination of these curricula will offer you valuable ideas for organizing and delivering sound science instruction. Each program can offer you a model for science teaching. Each model has been successfully tried and tested. Further, you should come away with ideas for activities presented in educationally sound ways. Finally, knowledge of these programs may allow you to integrate the programs in your own classroom or, perhaps, into your school if you are called upon to serve on a science curriculum adoption committee.

Science Curriculum Improvement Study (SCIS)

The first major program with which this worktext will deal is the *Science Curriculum Improvement Study* (SCIS). SCIS was developed at the University of California, Berkeley, with the help of monies contributed by the National Science Foundation. The original SCIS program materials became public domain in the mid 1970s. The publisher of those materials at that time, The Rand McNally Company, decided to produce a modified version of the SCIS materials. They subsequently published it under the program name, Rand McNally SCIIS. Rand McNally turned this program over to Delta Education, Inc., which is now the sole supplier of SCIIS.

The SCIIS program effectively combines both the process and product sides of science. In fact, the SCIIS program blends the knowledge, skills, and attitudes of science into a functional science program. The developers of this program feel that the conceptual portion of science is crucial and that it can be developed as a function of well-developed activities. Thus, they feel that a science program should utilize its experiential base (process component) to develop concepts in hierarchical fashion both within and across grade levels.

The SCIIS program contains twelve units (six in the physical sciences and six in the life sciences) for grades 1-6. Therefore, each year of the SCIIS program finds children experiencing two units of instruction, one in physical science and one in biological science. These can be taught in either order. The major concepts involved throughout the physical science units are *matter* and *energy*. The life science units involve concepts regarding the *organism* and *ecosystem*. Woven into all these knowledge components is the important idea of *interaction* (i.e., the relation among objects or organisms that do something to each other and thereby bring about a change). Thus, interaction relationships are stressed as the student's conceptual knowledge increases in sophistication. The chart found on the next page names the units of the SCIIS program, identifies the grade level (1-6) of each unit, and identifies the major concepts taught in each unit.

The SCIIS program has a single unit called *Beginnings*, which is taught at the kindergarten level. The purpose of this entire year unit is to develop children's powers of observation, discrimination, and description. A wide variety of experiences and activities in the life and physical sciences is used. Through suggested games, puzzles, and other activities, the children develop their abilities to describe and compare objects by their color, shape, size, texture, odor, and sound. The concepts of number and volume are introduced. The experiences in this unit contribute to a growing understanding of science and to language development.

Philosophically, the developers of this program state the overall objective of SCIIS to be *scientific literacy*. Said literacy is achieved as a function of the meld of process experience, attitude formation, and conceptual growth of the child. It should probably be added that the conceptual framework of the program agrees with the perceptions of many educators with regard to the knowledge that is of considerable importance to all literate human beings. Given the rationality of the decisions concerning content and the success of SCIIS in developing this knowledge, the elementary school has a powerful and important science program in this one.

OVERVIEW OF THE SCIIS PROGRAM

LIFE SCIENCE - CONCEPTS	GRADE LEVEL	PHYSICAL SCIENCE - CONCEPTS
ORGANISMS organisms habitat birth food chain death decay	1	MATERIAL OBJECTS object serial ordering property evidence material
LIFE CYCLES growth genetic identity development plant and animal life cycle metamorphosis	2	INTERACTION AND SYSTEMS interaction evidence of interaction system interaction at a distance
POPULATIONS population animal-eater plant-eater plant-animal-eater food web predator-prey biotic potential	3	SUBSYSTEMS AND VARIABLES subsystem histogram solution variable evaporation
ENVIRONMENTS environment range environmental factors optimum biotic abiotic	4	RELATIVE POSITION & MOTION reference object relative position & motion polar coordinates rectangular coordinates
COMMUNITIES pyramid of numbers consumers raw materials decomposers reproduction photosynthesis community food transfer producers competitors	5	ENERGY SOURCES energy source energy receiver energy transfer energy chain
ECOSYSTEMS ecosystem pollution water cycle food-mineral cycle oxygen-carbon dioxide cycle	6	SCIENTIFIC THEORIES scientific theory electricity color light ray magnetic field

SCIIS is inquiry oriented, and therefore, highly inductive in its learning experiences. For example, in the first grade children build aquaria with water, sand, plants, fish, and snails. The students observe the aquaria from a number of different perspectives. In a few weeks they notice that a black material has accumulated on the sand in the aquaria. The students' curiosity leads them to wonder what this black "stuff" is and where it came from. Traditionally, the teacher would *tell* the children that this black material is called *detritus* and that it originated with the death and decay of animals and plant parts and the wastes of living organisms. Here it would probably end. In SCIIS, however, the children pose hypotheses to account for the origin of detritus and set up experiments to test their hypotheses. Later they compare the growth of seeds in sand to which detritus has been added with growth in sand lacking detritus. Not only do children get a good concept of detritus, but more importantly they begin to perceive the *interactions* that take place between organisms and between organisms and their abiotic (non-living) environment. They also receive experiences with intellectual processes such as observation, hypothesizing and experimentation.

Interestingly, SCIIS does not rely solely on the laboratory experience for learning and sustaining learning. At various times in the program, field trips are utilized to help facilitate conceptualization. Numerous out-of-class activities lend themselves well to the conceptualization of such ideas as habitat, population, community, plant eater, environment, producer, ecosystem, and pollution. Similarly, discussions are promoted between children and between teacher and children. The discussion might be initiated by the teacher utilizing divergent questions to stimulate a variety of student responses. Or, if the teacher desires to check on the acquisition of knowledge, convergent questions may be used. Children can go to books to gain more information on a number of topics. However, success in SCIIS is not predicated on a child's ability to read, because the child can always turn to the real three-dimensional world in which he lives for information. Once again, we find a science program suitable for a wide range of student ability levels. In fact, it was observed during extensive use in urban, rural and suburban schools that the earlier editions of the units proved to be particularly helpful as part of the overall effort to improve children's oral language skills. The same potential exists with the current edition. The experience with real and interesting materials is especially effective in the case of disadvantaged or deprived children whose desire to speak and participate in class discussions increases dramatically.

The SCIIS teaching format is not organized into tightly structured lessons. Rather, a unit is composed of several parts, each having specific behavioral objectives. The parts, in turn, are divided into chapters. Each chapter may contain several activities as well as suggestions for optional, extension lessons.

The SCIIS program uses a specific instructional strategy which is based on the Piagetian theory of intellectual development. The strategy is called The Learning Cycle (which is discussed in depth in Chapter Five). The Learning Cycle has three stages, namely *exploration, concept introduction,* and *concept application* which reflect a sound inductive pedagogical approach to concept formation.

In the exploration stage, students do just that (i.e., children learn through their own spontaneous behavior by investigating and examining objects and events with minimal guidance in the form of teacher's instructions or specific questions). The materials the children explore have been carefully chosen to be easily used and to generate certain questions that the children have not asked before. For example, students may make observations regarding the behaviors of crickets and a chameleon which have been placed in a grass-filled terrarium. They observe that much of the grass disappears and that the number of crickets decreases over time. This set of observations may generate questions such as : What happened to the grass? Where did the crickets go? Did the chameleon have anything to do with the disappearances? These observations and questions provide the intellectual framework for the next stage in the learning cycle–*concept introduction.*

The concept introduction stage serves as the point where the teacher assists the children in interpreting the phenomena they observed during the exploration lesson. The spontaneous learning done during exploration is limited by the child's preconceptions. Children need concepts to help interpret and "nail down" their observations. Since few children can phrase new concepts by themselves, the teacher at times must provide a term and a definition for a new concept. In the terrarium example given earlier, the students have the observations necessary to develop the concepts of predator, prey, plant eater, animal eater and food chain. It is during the concept introduction stage that any or all of these concept labels and definitions can be introduced to the child by the teacher. After concept introduction, the teacher can give the children opportunities to use the new concept and encourage them to look for other examples that illustrate the idea.

In the concept application stage which follows concept introduction, students engage in different activities selected to allow them to discern a new application for a concept. Going back to the terrarium example again, the teacher might arrange a field trip during which the children identify other predator-prey relationships. Or, a film which depicts this relationship in a variety of settings (e.g., pond, ocean, forest, grassland) could be shown and discussed by the class. The children's concept application activities (which culminate the learning cycle) reinforce the original concept and enlarge and refine its meaning. In this way, mastery and retention of concepts are aided by practice and repeated, wide application.

One SCIIS activity may extend beyond a single class period or several activities may be included in one session. Certain activities, such as the investigation of pulley systems and the magnetic box puzzles are intended for small group or independent study. Other activities are more successful when a larger group or the whole class works together.

Flexibility of the teacher is imperative. So is inservice education of teachers. Successful implementation of SCIIS into a total school district is predicated on a successful orientation of teachers to the goals and methodologies of SCIIS.

As indicated earlier the SCIIS program includes two units per year for grades 1-6. Each unit contains equipment, supplies, a teacher's manual, student data collection booklets, and EYE cards. Replacement packages for consumable supplies are available, so teachers can replenish expended materials and student booklets each year.

Regarding evaluation, the teacher's manual contains evaluation activities based on the program's behavioral objectives. Also included in the teacher's manual are evaluation suggestions for the students' scientific attitude development. Additionally, methods for obtaining student feedback evaluation revealing the pupils' perceptions of the classroom environment is provided.

Finally, a set of between twenty and forty activity cards called *Extending Your Experience* (EYE) cards are included with each unit. EYE cards were developed for remedial work, small group activities, and individual student independent investigation.

Full Option Science System (FOSS)

The second program with which this work text will deal is the Full Option Science System, commonly known as FOSS. It is commercially published by the Encyclopedia Britannica Encyclopedia Corporation, as the Britannica Science System. FOSS is a true program organized around four major themes of science with twenty six different modules of supporting instructional materials including printed materials, student equipment kits and media such as videotapes and videodisks. The modular organization of the program is one of its primary features, providing flexibility for its use in a wide variety of elementary school settings.

Goals of FOSS

FOSS was developed by a team of teacher-researchers, directed by Dr. Lawrence F. Lowery, at the Lawrence Hall of Science, University of California. The program is an outgrowth of a philosophy that has guided the extensive science curriculum development at the Lawrence Hall of Science for more than a quarter century. FOSS is aimed at the goals of developing scientific literacy for students and providing instructional efficiency for teachers. It is important to note that the teaching and assessment methods used in the program are designed to involve all students and all teachers, not just a select few of either.

Achieving the goal of scientific literacy in the FOSS program means preparing students with basic science experiences that will lay the foundation for their ability to function in a world that is increasingly dependent on an understanding of science and technology. Students not only need to be aware of science ideas, but must also be able to use them in responsible decision making. The FOSS program embraces scientific literacy as characterized in the American Association for the Advancement of Science Project 2061 Report. Familiarity with the natural world, understanding the "big ideas" of science, recognition of science, mathematics, and technology as interdependent human enterprises, developing the ability to think scientifically, and employing scientific thinking skills in personnel and societal decision making are primary attributes of scientific literacy.

To achieve its "instructional efficiency" goal the FOSS program addresses a number of issues of concern to teachers in present school settings. A major barrier to the implementation of hands-on science has been the lack of instructional materials. The FOSS program provides complete kits of student equipment. The equipment for each modules comes in one or two boxes, with an additional measurement kit required for most lessons. The problems and time costs associated with gathering and organizing science materials are minimized in the FOSS program.

Another barrier to hands-on science in elementary schools has been "science phobia." With the FOSS program a teacher does not need to be an expert in either science or science teaching strategies. Activity folios written for teachers provide both science background information and a step by step teaching plan for all lessons. This material is written in a concise, non-technical manner providing many ideas for both the beginning and experienced teacher. Videos for teachers show how to assemble equipment and teach lessons. Ideas for interdisciplinary activities, related readings, multicultural applications, and enhancing lessons with videos and videodisks are included for teacher consideration. Student data sheets and assessments of different forms are found in each activity folio. The design of the FOSS program should reduce "science phobia" and preparation time of the first time teacher user.

FOSS Philosophy

The FOSS program is designed to correlate with the cognitive development of learners. The experiences and activities of the program modules are designed to match the abilities of the students who will use them. In the early elementary modules the activities center on observation, description and classification of objects. For example, in the Wood Module for kindergarten, students observe and compare blocks of different kinds of wood. Modules for students in the upper elementary grades involve activities where students collect and analyze data to determine cause and effect relationships through experimentation. In the Variables Module, fifth or sixth grade students conduct an investigation using a flip stick to try to determine how changing the angle of launch will effect the distance an aluminum ball will fly. FOSS is unique in that the science process skills are specifically and sequentially related to the cognitive stages of the learners. The thinking processes scope and sequence of the FOSS K -6 program is displayed on the chart that follows.

FOSS *Thinking Process* Scope and Sequence

Grade	Observing	Communicating	Comparing	Organizing	Relating
K	√	√	√		
1, 2	√	√	√	√ Beginning	
3, 4	√	√	√	√ Advanced	
5, 6	√	√	√	√	√

FOSS Scope and Sequence

The program is organized around four major themes. These are Life Science, Physical Science, Earth Science, and Scientific Reasoning and Technology. There are four modules in each of these areas covering grades three through six. At grades one and two the three of these themes are covered. There are two modules each for Life Science, Physical Science, and Earth Science. At kindergarten the Life and Physical Science themes are covered with two modules available for each. The content scope and sequence of the FOSS K -6 program are displayed on the following page.

FOSS Teaching Strategies

Hands-on activities are the primary instructional approach used in the FOSS program. Research indicates that this method is most effective in helping students construct a foundation of science knowledge and skills and develop positive attitudes toward science. FOSS activities are inquiry oriented and based on the learning cycle instructional model. Students start an activity by exploring, or observing some object or event. They may collect data about what they are observing in the form of drawings or numbers. Observation may include any of the five senses depending on the activity. Following the open-ended exploration phase of the activity there is a discussion of the student findings where new terms and concepts are introduced by the teacher. Additional hands on or multimedia experiences are used to reinforce or show application of the lesson concepts. One activity provides a basis for others in the folio thus creating a cycle of learning.

The FOSS program is designed around students working in groups. This has the advantages of conserving materials and allowing students to share ideas and learn from others. Further, students discover that science involves people working together. At the third through sixth grade levels students work in collaborative groups of four where each takes on a specific role of reader/reporter, getter, starter, or recorder. Groups work together to achieve common goals. At the kindergarten through second grade levels students work in clusters of four to ten students but not in a true collaborative manner. Each student in the cluster has the same materials and is doing the same activity but the sharing process is informal and not as deliberate as is the case with upper elementary students. The cluster grouping approach used with early elementary students is called "working alone together."

The authentic approach to assessment is used in the FOSS program. Since the program goes beyond simply teaching science facts or vocabulary, recall type tests (true-false, fill in the blank) are not appropriate. Three alternative assessment approaches are used in the program. These are hands-on, pictorial, and reflective question assessment. These devices measure students' understanding of science concepts and their ability to do science and to apply scientific knowledge.

Hands-on assessments use materials from the modules and ask students to *perform* certain tasks related to the concept and skills developed in the module. For example, in the Variables Module one of the hands-on assessments asks students to construct a five paper clip pendulum. They are then asked to determine how many swings it makes and how they could make sure their count is correct. They are then asked to change the pendulum so that it will swing a greater number of times in ten seconds than before. Hands-on assessments are conducted with the student working at a "station" that includes the necessary manipulatives. Multiple stations are set up to efficiently assess all students in a classroom, with students taking turns at the stations. Students should be advised to focus on their own work during such assessments.

Foss *Content* Scope and Sequence

Grade	Life Science	Physical Science	Earth Science	Scientific Reasoning and Technology
K	Trees	Wood		
	Animals Two by Two	Paper		
1 & 2	New Plants	Solids and Liquids	Air and Weather	
	Insects	Balance and Motion	Pebbles, Sand, and Silt	
3 & 4	Structures of Life	Physics of Sound	Earth Materials	Measurement
	Human Body	Magnetism + Electricity	Water	Ideas + Inventions
5 & 6	Environments	Levers and Pulleys	Landforms	Variables
	Food and Nutrition	Mixture and Solutions	Solar Energy	Models and Designs

A hands-on assessment is scored by the teacher making a judgment of the student's performance on specified tasks. For third through sixth grade students, this is generally done by reading responses written on the assessment sheet and deciding if the response is appropriate and well stated, appropriate but not well stated, or inappropriate. A symbol of +, n, or - is then marked under the related criterion on the *Hands-on Assessment Chart* by the teacher. For kindergarten through second grade, assessment is conducted informally throughout instruction by the teacher asking the students questions. For example in the Wood Module, after observing different kinds of wood, students go on a wood hunt to find a matching piece in the classroom. To assess the students, the teacher calls out the name of a wood such as redwood and asks all the students who found a piece of redwood to raise their hands.

FOSS also uses pictorial and reflective question assessments with upper elementary students. Pictorial assessments involve a line drawings depicting some objects or events where students apply what they know to answer an application type question. For example in the Variable Module, one of these assessments pictures a catapult firing a stone that comes short of a wall. The question asks the student to list all the things they could change to make the stone go over the wall. Reflective questions present descriptions of situations where students use what they learned in the activities in a different way. For example a reflective question in the Variables Module describes the procedures and results of a simple, but flawed experiment for testing what kind of cloth dries quickest and asks the student to describe two ways the experiment could be improved.

Student Equipment Kits

Each FOSS module is physically organized around a student equipment kit. A kit contains all the specialized materials and consumables needed for teaching the lessons in the activity folios. Common consumable materials such as string, tape, flour and vinegar are to be obtained by the teacher from a local source. Living organisms used in some of the kits are either obtained locally or from national suppliers by sending in prepaid order cards included with the kit. Each kit provides enough of the specialized materials and consumables for a class of thirty two students working in small groups. In addition to the manipulatives, grade 3-6 kits include a teacher preparation video, while all kits include the Teachers Guide for the module, the components of which are described below.

Teachers Guide

The Teachers Guide for each module is a three ring loose leaf binder that contains five major components. The Introduction section describes the FOSS program in general with an overview of its purpose and philosophy, its organization, instructional approach and materials. The Introduction section also includes a two page scope and sequence chart showing the organization of the twenty six FOSS modules by grade level and science topic area. A brief synopsis of each of these modules is also provided in this section.

The second section of the Teacher's Guide is the Overview. The purpose and goals of the module as they relate to science content and processes are described in this section. A primary function of the Overview section is to provide the teacher with in-depth science content background related to the unit. Additionally, this section briefly describes the activities in the module, and provides information on scheduling and organizing them for maximum effectiveness with all students.

The Activity Folios are the heart of the FOSS Teacher's Guide. Each folio describes several lesson plans related to each other and to the topic of the module. The background for the teacher and quantity and kinds of materials needed for the lessons including manipulatives and student worksheets are identified near the front of each folio. Following this, the individual lessons are described in a step by step manner in a sub-section called "Doing the Activity." The folios also contain discussion questions for getting students to reflect on the lesson concepts as well as suggestions for extending or applying lesson concepts. Furthermotre, suggestions for integrating the lessons with mathematics, language arts, and social studies are made. The folios are completed with a sub-section called "FOSS for All Students" which provides ideas for using the lessons with diverse populations. These include, but are not limited, to visually impaired, physically disabled and learning disabled students.

Printed Material for Students

There is no FOSS textbook. The Teacher's Guide contains duplication masters of worksheets used with lesson activities. Some of the worksheets give step by step directions students use to build apparatus such as the Flip Stick Construction Worksheet in the FOSS Variables Module. Other worksheets guide students through activities such as the Flipping Aluminum Balls Worksheet, or are used as data tables such as the Flip Up Worksheet, also from the Variables Module. All worksheets come in both English and Spanish versions.

Each Teacher's Guide contains a FOSS Activity Correlation Table, known as a FACT sheet that includes suggested student readings, teacher resources and computer software to match module activities. The student readings section lists science trade books as well as literature selections. For example, for the Variables Module the books Amelia Earhart: Aviation Pioneer by Roxane Chadwick (non-fiction) and Dirigible by Joshua Stoff (fiction) are listed.

Another kind of printed material for students are the FOSS assessments. These are also found in the Teacher's Guide and, as previously mentioned, include three types: hands-on, pictorial and reflective questions. These are designed to assess student understanding and ability to apply both science process and content of a module. All assessment sheets come in both English and Spanish versions.

FOSS Multimedia

The FOSS program provides for the possibility of multimedia science instruction using some of the more recent technologies. While the hands-on manipulatives in the equipment kits provide opportunities for concrete learning experiences, video enables the teacher to enhance the learning context with visual excursions to places or events not accessible in the classroom. FOSS provides video-based instruction for both teachers and students. The program incorporates both videotape and videodisk formats. The video resources provided with the program are described below.

Science Essentials provide the video components to support multimedia science instruction for ten of the sixteen FOSS modules. The videos are available in VHS tape and videodisk formats. Each video focuses on a broad topic area in science. Video titles include: Animals, Ecosystems, Electricity and Magnetism, Geology, Human Body, Learning About the Earth, Learning About Energy, Learning About Environments, Learning About Matter, Learning About Plants, Heat, Light, Oceans and Space, and Weather.

Each video contains a number of short segments illustrating one or two concepts related to the broad topic area. For example, the Geology video has a series of segments showing shots of different land forms and another series showing examples of how vegetation effects the surface of the earth. The Human Body video illustrates how the body works including movement, eating, breathing, and sensing the environment. These segments provide students the opportunity to observe objects, events, and experiments related to their classroom activities. The video segments may be used to supplement such activities or assess student understanding of them. The FOSS program advocates the true integration of video with other instructional components; this is not a program where the teacher receives a slection of tapes to simply show to students!

A Multimedia Materials section is found with the Teachers Guide for each module incorporating video. It describes how to use the video with the lessons in the module, how to prepare for doing this, and where to find the video segments. Bar-codes are provided for each lesson so that videodisk users can conveniently access the appropriate images. An Index/Glossary cross references science topics with FOSS modules and specific activities and Video/Videodisk titles and frame numbers. This also allows the video to be used at Level III for presentation, research, and video report projects.

Chapter Eight

Science Textbooks: Analyzing and Modifying Them for Use in the Classroom

Subsequent to your interaction with this part of the worktext, you will be expected to be able to. . .

1. . . . describe specific mechanisms that can be employed by the elementary teacher who is using a textbook series to make certain that at least some of the Project Synthesis goals can be covered. Similarly, describe how these strategies should be used to facilitate scientific literacy.

2. . . . explain why a school district should have its science education goals sharply in focus before attempting to choose a science textbook program. (In other words, this implies that texts vary—and, they do! Know how they vary and how this could relate to the philosophical setting of the school district. For example, consider such potentially controversial topics as reproduction and evolution and how these topics are presented.)

3. . . . describe how textbooks differ in terms of whether activities promote inductive or deductive learning. Make certain that you can explain the differences you would have to observe to determine whether the learning was inductive or deductive in nature.

4. . . . cite several examples of characteristics one should look for in a Teachers Guide in a science textbook series and explain why these characteristics are of significance to the teacher.

5. . . . describe, citing specific attributes, the ideal science textbook for use in the elementary school. Defend your description in terms of scientific literacy and teaching effectiveness.

6. . . . (on the basis of your own textbook analysis) develop a chart that lays out both strengths and weaknesses of elementary science textbooks. Be prepared to defend your selection of strengths and weaknesses.

Science Textbooks:
Analyzing and Modifying Them for Use in the Classroom

Without a doubt, the science textbook series is the most common vehicle used for the teaching of science in the elementary school classroom. This fact could easily imply that science textbooks fulfill the scientific literacy goals outlined in Chapter Two of this worktext. How accurate an inference is this? Rather than give a simple yes or no answer to the question of textbook effectiveness, the writers will let you make up your own mind. This chapter will provide you with strategies on using and supplementing a science textbook in your elementary classroom. With those strategies in hand, you will then be asked to thoeoughly analyze an elementary science textbook with regard to both its educational potential and its potential for addressing the goals for scientific literacy.

Strategies for Using the Textbook for Literacy

Below, you will find listed a number of sound suggestions for teaching for literacy if you are using a textbook program in your school. Although the discussion of these strategies may be brief, they should be taken with the utmost seriousness. An appropriate meld of these methods will greatly enhance your helping your students achieve scientific literacy.

1. Infuse Locally Significant Science-Related Social Issues Into Your Science Program.

This particular strategy is particularly pertinent to the Societal Issues Goal Cluster of Project Synthesis. Issues of this type would include those that relate to medicine, business and industry, population density pressures, land use management, sewage disposal, solid-waste management, zoning, etc. Regardless of the sensitivity of the issue, children should have an opportunity to explore the various sides of the issues, debate the solutions, and become knowledgeable about what is happening in the socio-scientific world surrounding them. Do not hesitate to provide this opportunity although your teaching posture should be value-fair i.e., you should not attempt to superimpose your own values on the students). (Note: An entire chapter of this worktext deals with environmental education and focuses on many of the elements associated with issue investigation and values clarification).

2. Use Local Resources And Resource People In Your Science Program.

Far too few teachers are willing or able to make use of community resources in their teaching. In almost all communities—large or small—live people who are more than willing to share their expertise with the children and/or the teacher. Further, there are physical resources in ALL communities (school districts) which are valuable teaching tools. Some progressive school districts have actually inventoried local/regional resources available to teachers and made these inventories available to every teacher. In other instances, agencies beyond the school itself have inventoried resources which have educational significance. In some cases, these inventories are produced as manuals; in other cases these resource inventories are computerized. In some situations, teaching staffs have received training in the use of those inventories. This training has been shown to be extremely effective. Using the community/region as a profitable part of the science program can pay rich dividends. Resource people can help tremendously in the career awareness phase of your program or to help make science concepts become more meaningful. Similarly, visiting a hardwood forest or a desert or a swamp or a zoo, etc., can make the textbook come alive if appropriate strategies are employed. Further, and equally or more important, is the fact that many community resources will permit instruction on literacy components which are ignored by or absent in the text.

3. Focus On The Processes Involved In Science Activities (As Well As The Concepts).

One of the major weaknesses of many textbook series is that they talk about the development of process without really doing it. During a science activity, students need to know what kind of mental activity they are engaging in. This will help them develop the skill further. If a science activity involves a good deal of observation, discuss the elements of scientific observation before the activity so that students can practice the skill knowing precisely what it is they are doing. The same would hold true for any other process (e.g., inferring, data interpretation, experimentation). This will, in no way, interfere with the acquisition of the desired conceptual content. In fact, it may enhance it.

4. Generate Process Development Activities If Certain Skills Are Not Covered In The Text.

Oftentimes, it is obvious that students will not have an opportunity to develop particular science process skills even though there may be numerous activities in the text itself. For example, in many instances, there is no true experimentation in the science textbook (regardless of what the activities may say in their titles). Certainly middle school students can and should learn the rudiments of true experimentation. At times, activities for the sake of process acquisition per se are called for. How does one accomplish this? There are often many ways to go about setting up scientific experiments which correlate well with the text's content. This takes a bit of creative thought on the part of the teacher. Most certainly, if process acquisition is important, it is not crucial that the process activities correlate with existing curricular content. Examples of such activities can be found in this methods book. Most, but not all, will be found in the chapter dealing with science process. Use them as they are, or modify them for use with your age group. Many more ideas can be gleaned from FOSS or SCIS teachers' guides.

5. Don't Be Limited By A Lack Of Commercially Prepared Equipment.

Far too often, teachers will say, "I can't do activities with my children because I don't have the equipment, and my school district will not provide it." In the opinion of the writers, this is a weak excuse for conducting a "read about science program." Many, many good elementary teachers have found that, in order to provide a rich, exciting science program for their students, they are going to have to make, beg, borrow, and even purchase some materials. Unfortunately, this is often simply a fact-of-life. You will recall that many of the activities used in this methods book utilized inexpensive and locally-obtainable materials e.g., candles, matches, rulers, coins, jars of various sizes, graph paper, water, washers). It is beyond comprehension that any teacher can logically argue the inability to obtain these kinds of things. Even more sophisticated equipment can be constructed by the teacher (or by a spouse or friend). Examples are the construction of pendulum stands out of inexpensive or scrounged wood, making large aquaria out of plate glass or refrigerator liners (often available in junkyards), terraria out of double strength glass and a heavy binding tape (or even out of large jars—plastic or glass), geometric blocks out of 2 X 4's, etc.

6. Keep Up On The News (Television, Magazines, Newspapers) And Share Science Events With Children.

Help students keep up with the growing body of knowledge in science by watching TV and reading science news in periodicals. Although it is NOT recommended, there are so many sources of information on new events in science that you could structure a science program around this content all by itself. Periodicals such as Newsweek and Time help keep the public abreast of new advances in the pure sciences, space travel, medicine, and computer science (among other things). Keep up on the news and share it with the children. Don't hesitate to have them report on things they have read, seen, or somehow heard about outside the classroom. Of course, many teachers will have, as part of the classroom library, recent issues of National Geographic, National Wildlife, Ranger Rick's Nature Magazine, Audubon, and other popular periodicals for children and adults. These are also highly recommended.

7. Infuse Science Into Other Subjects.

A number of science textbooks promote the use of science content in other subject matter areas, e.g., math, language arts, and social studies. If a topic is being studied that truly excites the children, why not turn it to your advantage through composition, outside reading, panel discussions (or debates), etc.? Research has shown rather clearly that elementary students are particularly interested in animals, prehistoric life, certain aspects of earth science (volcanoes, earthquakes and the like), and reproduction (in the later years). These interests, carried over into math and language arts would most certainly pay rich dividends as content vehicles for skill development outside the science arena per se. (NOTE: An entire section of this methods book is devoted to the methods associated with the use of incidental science experiences and, therefore, this topic will not be treated here.)

8. Promote Student Viewing Of Scientific Television Programming.

A surprising number of science-related programs have been and are being prepared for television. Although not limited to it, the PBS is a rich source of valuable viewing for children. Although not all such programs may be suitable for the elementary child, many are. A judicious selection of National Geographic Specials, NOVA Programs, Costeau Specials, the Life on Earth Series, the Cosmos Series, the Body Human, and others are rich in information for children. It should be remembered that many of these programs will bring the child into contact with illustrated content that would be next to impossible to communicate otherwise. A rich and diverse reservoir of educational viewing is there for the asking—free, motivating, usually well produced, colorful, entertaining, and often extremely valuable from a scientific literacy perspective.

9. Sharply Dichotomize Between Science And Technology Whenever The Opportunity Arises.

Most textbooks (if not all) will treat both pure science content and technological content similarly, i.e., publishers present both as content without differentiating between the two. In the opinion of the writers, this is a fatal mistake. Students must understand the differences even though a close relationship exists between the two. Because this subject is dealt with elsewhere in this worktext, it will not be treated in more detail here.

10. Use Concrete Examples Whenever Possible.

Although the textbook has a major advantage over other science programs in that it can present information that cannot be learned via first-hand student experiences, it also has a potential that is often unrealized in the classroom. That potential lies in using concrete (real) examples of many of the concepts under development. Why read about frogs and not have one in the classroom? Why read about flying and not use model airplanes or the real thing at the local airport? Why read about soil types and not look at soil samples from the area? Why read about soil erosion and not put in a simple erosion control project on the school grounds or in the neighborhood? Why read about birds and not bring a live bird in from the pet shop, or bring in a bird fancier or an accomplished bird watcher, or put up a bird feeder outside the window of the classroom? Yes, why not? There are few good excuses for not doing these things and a myriad of educationally sound reasons for doing them. You know enough about how children learn best to realize how true this last statement is!

Analyzing the Science Textbook Series

Training in and experience with textbook analysis is a practical enterprise for the science methods student. Most elementary teachers, at one time or another, must bear the responsibility for textbook selection. Similarly, you may well have a science textbook to work from on your first teaching assignment. It is expected that the analysis you will be conducting will further familiarize you with the textbook as a teaching device. This analysis will also help you examine some of the criteria the writers deem important in the selection process.

It behooves anyone considering textbook programs to compare products judiciously. To ignore the main objectives of science education in the local school's program is educationally unsound. Textbooks DO differ and accomplish different ends even when used with the greatest skill.

This assignment requires you to carefully analyze a particular science textbook program from several important standpoints. This analysis does not deal with many of the traditional criteria employed in textbook evaluation (e.g., reading levels). Instead, the criteria reflect, insofar as possible, scientific literacy itself, the advantages that can be gained by using a text, some of the disadvantages, and the ways in which the textbook can be modified in order to provide a sound science education experience of general education value for children. For the most part, the criteria employed are consistent with the goals of Project Synthesis—those goals so urgently required for the development of a scientifically-literate citizenry.

TEXTBOOK APPRAISAL

Your Name ______________________________ Date __________

Title of Textbook ______________________ Grade Level Chosen _____

Author(s) ____

Publisher ______________________ Publication Date __________

Content Included in the Textbook

Please examine the textbook carefully. Below you will find listed the major content areas recommended by the National Science Education Standards for inclusion at various grade levels. Please check those which receive substantive coverage in the textbook which you are analyzing.

Levels K-4

___ Properties of objects and materials
___ Position and motion of objects
___ Light, heat, electricity, and magnetism
___ Characteristics of organisms
___ Life cycles of organisms
___ Organisms and environments
___ Properties of earth materials
___ Objects in the sky

Levels 5-8

___ Properties and changes of properties in matter
___ Motions and forces
___ Transformations of energy
___ Structure and function in living systems
___ Reproduction and heredity
___ Regulation and behavior
___ Populations and ecosystems
___ Diversity and adaptations of organisms
___ Structure of the earth system
___ Earth's history
___ Earth in the solar system

PART I—SCIENTIFIC LITERACY

Personal Needs Goals

1. Is there evidence in the student text to indicate that students gain a concept of what science is? This could be accomplished through a direct definition, discussion, or through repeated reference to science. Although a child might gain the concept inductively, by experiencing science in a realistic manner, you must provide an adequate explanation if you use this perspective in your answer.

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

2. Does the textbook cover mental and/or physical health as a basic part of science? In particular does it assist children in forming good health habits and valuing a healthy body/lifestyle?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

3. Does the textbook enable children to be successful consumers in a scientific and technological society?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence

Societal Issues Goals

4. Does the textbook present information dealing with science-related social issues? Examples of these issues might include endangered plants and animals, soil erosion, acid rain, human population growth, etc.

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

5. Does the textbook develop an appreciation of both the potential and the limitations of science and technology with respect to solving societal issues?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

6. Does the textbook help students develop the abilities to analyze science-related social issues, and to make sound decisions and deal responsibly with those issues

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Academic Preparation Goals

7. Does the textbook cover a variety of important science concepts?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

8. Do students receive training in specific scientific processes in this series, e.g., hypothesizing, comparing, classifying, predicting, and experimenting?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence

9. Does the textbook provide for the development of scientific attitudes (e.g., respect for empiricism, curiosity, demand for verification, suspended judgment)?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Science Career Awareness Goals

10. Does the textbook develop an awareness of scientists and technicians as real people?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

11. Does the textbook present information on a wide variety of careers related to science and technology?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

12. Does the textbook present illustrations of or anecdotes about individuals of both genders, numerous ethnic groups, and various handicaps in science-related careers?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

PART II—INSTRUCTIONAL APPROACH

Questions

Questions are asked of students in all science texts. They are found interspersed within chapters, at a special section at the end of the chapter, or in both places. Please study the manner in which the authors have asked those questions.

13. Do the authors ask questions which measure the acquisition of concepts rather than simple recall?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

14. Do the authors ask questions which measure the ability of the child to apply concepts in new and unique situations?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Activities

Most texts claim that they are activity (experientially) oriented and support hands-on science education. Their activities, often called experiments or investigations, are found interspersed within chapters or units, at a special section at the end of the chapter, or in both places. Carefully examine the manner in which the authors have presented these activities.

15. Are the activities structured in such a way as to have the students inductively form a concept? That is, do the students experience hands-on science before they read about or discuss a concept

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

16. Are the activities developed so that there is an opportunity for open-ended, independent investigation, rather than simply following a prescribed sequence of events which lead to a predetermined answer?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Evaluation

17. Are the children evaluated in a manner which is consistent with stated objectives and/or textual material?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Concept Development

Most textbook publishers make a point of noting that a particular text develops important concepts. Choose any one specific concept from anywhere in the text, state the concept below, and continue with this part of the appraisal as directed below. (An example concept: Energy is exchanged in the environment through food chains beginning with the food-producing green plant.)

State the chosen concept in this space:

Page:

18. What printed information and/or illustrations are found in the text which would help the child develop this particular concept?

19. What science experiences (laboratory or otherwise) do students get with regard to this particular concept? In other words, what do students DO to help them learn this concept?

20. What suggestions are there in the Teacher's Guide for the development of this concept?

21. Do your answers to questions 18, 19, and 20 above provide enough information and experiences to permit the thorough development of this concept? Defend your answer! Think it through carefully!

The Teacher's Guide

22. Please inspect the Teacher's Guide for the text that you are analyzing. Respond to the following:

Does the Teacher's Guide ...

a.... clearly present instructional objectives for each unit/chapter? Yes No

b.... provide the teacher with adequate supplementary information on the science content being presented to the students in each unit/chapter? Yes No

c.... provide the teacher with lists of resources he/she may go to for further information on the science content being presented in each unit/chapter? Yes No

d.... communicate teaching methodologies which would maximize teacher effectiveness in teaching the units/chapters? Yes No

e.... provide the teacher with descriptions of supplementary materials (e.g., films, filmstrips, videos, trade books) which could be used profitably with students? Yes No

f... provide suggestions to the teacher for integrating science content with other content areas in the curriculum (e.g., reading, social studies, composition, mathematics)? Yes No

g.... reflect an organization which would facilitate the teaching of the unit/chapter (i.e., make the teacher's task easier and more efficient)? Yes No

SUMMARY

You will now be asked to make a recommendation regarding the use of this science textbook series. Assume that, for one reason or another, you had to use this textbook series as the basic science program. Please think this through carefully, as you do the following:

23. List what you believe to be the major strengths of this textbook series as related to scientific literacy.

24. List what you believe to be the major weaknesses of this textbook series in relation to scientific literacy.

25. Prepare a detailed explanation of how you would use this series, modify it, or supplement it, in order to provide the best possible science program for our youngsters. In other words, how could we use this series to provide for scientific literacy on the part of our students? Please be very specific in your response.

Chapter Nine

Beyond the Textbook

Subsequent to your interactions with Chapter Nine you will be expected to be able to . . .

1. … defend the idea that local and community resources should be used in the teaching of science.
2. … list several kinds of community resources that could be used by the elementary teacher and describe how each might be used instructionally.
3. … demonstrate an ability to identify and inventory a usable community resource.
4. … explain how a field trip should be organized to maximize effectiveness for learning.
5. … explain why it is important for the teacher to be familiar with the field trip site.
6. … identify at least two ways in which the incidental science experience (I.S.E.) can be used as a vehicle to develop language arts skills.
7. … identify at least two reasons why the I.S.E. is a valuable strategy to use with culturally disadvantaged children.
8. … cite two examples of situations (other than those described in the reading) that could be defended as I.S.E.'s and specify how each could be developed into a science learning experience to develop conceptual knowledge.
9. … demonstrate the ability to teach an incidental science experience and produce a language experience chart subsequent to that experience.

Community Resources

A few years ago one of the writers of this methods book had occasion to join a team of educators that was assigned the task of evaluating a rural school in southern Illinois. This writer's responsibility was to evaluate the science curriculum. One of the first things he noticed was the school's setting. The school was out in the country. Just south of the school, no more than 100 yards away, was a large oak-hickory deciduous forest, unaltered and ripe for teaching ecological concepts. In front of the school was a wide ditch that was water-soaked. In spots, standing water could be observed complete with aquatic plants, water insects, and amphibians. Just across the highway lay a railroad track, and beyond the tracks was a very large segment of the Shawnee National Forest, which covered much of the region.

Seldom, if ever, had the writer observed a school with such rich natural resources available within a five minute walk of the classroom. Excited with the prospect of finding a rich science program for students, the writer observed several classes and spoke with the teachers about science instruction. An upper grade science teacher was interviewed last. He was quick to inform the writer that he didn't allow his students out of the classroom and therefore didn't use the resources that were so close to the classroom.

This situation is far more typical than one would like to admit. We often refer to the above situation as a "two by four classroom" (i.e., two covers of a book and four walls of a classroom). And, we are almost certain that students coming from such a classroom will only have limited ecological knowledge, will not be aware of the resources of the area, will not be able to investigate serious issues within the region, and will not know how to engage in efforts to resolve the important issues facing their community. In short, by not providing students with opportunities to interface with appropriate community resources as a part of instructional programs, we are seriously impairing students' ability to become scientifically literate citizens.

This scenario stands in sharp contrast to those situations where teachers have not only sought to make use of the school site as an outdoor classroom for their students, but who have worked with their students to either set aside, or even improve their school site for this purpose (e.g., with tree plantings, plantings for insects, birds, and mammals; brush piles as habitats; watershed or stream clean-ups; and the like).

In one local school district, the science coordinator worked with teachers in each building to develop lesson plans for their school sites. The science coordinator also arranged with local college faculty to provide teachers with an intensive inservice session focusing on the development and use of their outdoor classrooms. These are simple examples of how cooperation from a few key teachers and resource people can help to overcome the limitations of the "two by four classroom" by working to provide students with appropriate educational experiences using locally available resources.

Readers of this document should note that the above examples emphasized the use of one type of local/regional resource (i.e., school grounds) for instructional purposes. There are also other kinds of community/regional resources which could be used for instructional purposes. What are some other strategies associated with the use of such community/regional resources?

A Few of the Many Possible Resources Available for Science Teachers

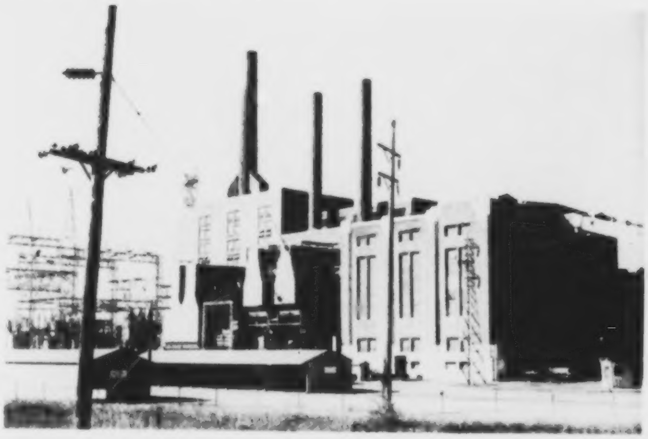
(All photos on this page are courtesy H.R. Hungerford)

Both national and state facilities are important as potential sites for education outside the classroom. Wildlife refuges, state parks, national monuments, national forests and other resources may be used very successfully for communicating important science concepts and for practicing important intellectual skills.

Crab Orchard
National
Wildlife
Refuge

A very old cemetery in the Big Bend region of south Texas yields a rich resource for the science teacher. Who is buried here? Can we identify them? What caused the death of these people and at what ages? Scientific implications? How is the desert ecosystem taking the cemetery back from human interference?

This coal-fired electrical generating facility is in southern Illinois. near the Mississippi River. Energy is critical to human existence. The sources of energy for heat, electricity, and other energy forms are numerous. Problems associated with them are also numerous. A carefully planned field trip to one of these facilities during an appropriate unit seems to be a sound educational strategy.



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Inventorying and Using Community Resources

One useful strategy for the science teacher is the development of "resource inventories." One of the authors of this text has been involved in a number of resource inventories in the United States over the past twenty years.

A resource inventory is a printed directory of both physical and human resources available for instructional use within a specified area. This inventory can take the form of a manual or book, it may be computerized, or it can simply be developed as a card file to be used by all instructors in a school program. Regardless of the form, it will be important to include particular kinds of information about the resource and its instructional use in an inventory. Once an inventory of this type is developed, the critical question then becomes "Who will use it?"

The teacher who wants to use local resources must become familiar with them and think through how they can be used!

Research is quite clear on the use of resources and resource inventories. Teachers who are familiar with area resources and who have thought through how to use them will use them far more than teachers lacking such experiences. Researchers have found that those teachers who were trained in the inventorying of community/regional resources, and who were actually involved in the inventory process, are the ones who will use those resources with their students to a far greater extent than will other teachers. With these thoughts in mind, the writers have included with this chapter: (1) a sample of a Resource Inventory Worksheet, and (2) a fictional Sample Resource Inventory. These are included for interested readers as general guides for use in developing resource inventories. The reader should feel free to use and/or modify the inventory form as is needed in her/his own particular situation.

What human resources can be inventoried for a resource inventory? A few examples would include resource people such as wildlife biologists, game wardens, botanists and greenhouse workers, commercial fishermen, trappers and hunters, ranchers and farmers, waste disposal personnel, waste water personnel, sewage treatment plant operators, energy plant operators, insect and pest control specialists, environmental organization activists, and local/regional government officials involved in environmental matters.

Examples of nonhuman resources or resource sites are things such as national/state wildlife refuges and parks, national/state forests, typical ecosystem sites, local parks having environmental potential, farms and ranches, zoos and botanical gardens, museums, fish hatcheries, sewage treatment plants, waterworks, garbage dumps (landfills) and other disposal sites, electrical utilities, mines and drilling sites, fertilizer industries, toxic waste dumps, university facilities such as departments of fisheries and wildlife, nature and environmental centers, and recycling centers. As may be obvious, the list of possible resource sites may be quite large.

Resources should be inventoried and used in sound science education programs.

The Resource Inventory Worksheet

Name of the Resource: ______________________________

Type of Resource: ______________________________

Content Area Supported: ______________________________

____

Address and Location: ______________________________

____

____

Appropriate Use for This Resource: Field Trip _______; In-Class Use _________;

Issue Investigation by Students __________; Other (Please Explain) ____________

____

Contact Person and Address: ______________________________

____

____

______________________________ Phone: ______________

Facilities: Shelter ________; Restrooms __________; Picnic Table ___________;

Accessible to Handicapped __________; Other ___________ (Please Explain)

____

Use Limitations/Restrictions: ______________________________

____

____

____

A Fictional Resource Inventory

Name of Resource: Bat Ears Wildlife Refuge.

Type of Resource: Federal Wildlife Refuge.

Content Areas Supported By This Resource: Elementary Science, Ecology, Environmental Science, Environmental Studies, Content Areas Supported, Methods in Environmental Education, Geography.

Appropriate Resource Use: Field Trip, Investigation by Students, Specialists Invited to Speak to Students in Class.

Address/Location: The Bat Ears Wildlife Refuge is located eleven miles west of Barnum. Written communication should be sent to:

The Refuge Manager
Bat Ears Wildlife Refuge
P.O. Box 1600
Barnum, ZZ 00459

Contact Persons and Address: Mr. Kevin Insell, Refuge Manager, or Dr. Gertrude Brewer, Wildlife Biologist, Telephone: 778-1420; 8AM—5PM.

Facilities: Shelter and Restrooms are available in the Main Refuge Building. This building also has a small auditorium. The two picnic areas on the refuge are available on a first-come, first-serve basis. Each picnic area consists of five sites, with two tables at each site. Rest rooms are also located there. An emergency phone is located in the main building at the secretaries desk (778-1420). All buildings are handicapped accessible.

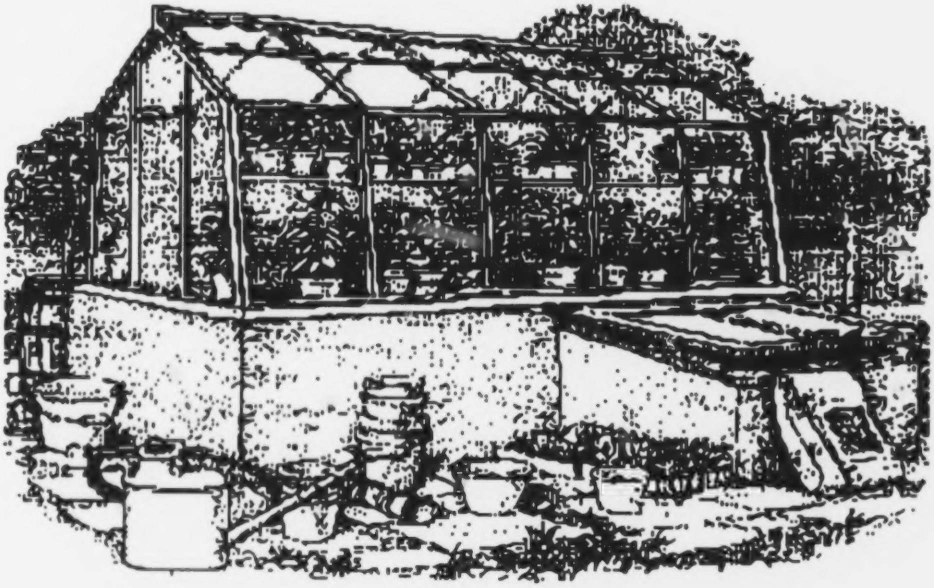
Suggestions for Use of the Resource: Bat Ears Refuge is an excellent place for students to observe/study the typical deciduous forest and pond communities. The refuge is home to ten species of endangered plants, and six species of endangered animals (i.e., birds, mammals, amphibians). Serious issues surround several of these animal species, and refuge personnel are willing to have supervised students observe/study these animals with some restrictions. Refuge personnel are also willing to speak to appropriate classes in schools within 20 miles on related issues with advance notice, or to be interviewed (in person, by telephone) by students conducting serious issue investigations. Migratory patterns of birds could be easily linked to regional geographic studies.

Use Limitations/Restrictions: Although the refuge may be visited by any school group making arrangements in advance, supervised college students are the only students who can gain access to certain areas due to the potential threat to protected animal species, and potential danger to the students. Students will not be allowed in designated areas during certain nesting, rutting and mating seasons. Not all trails are handicapped accessible. There is a special interpretive trail for visually impaired.

Field Trips

Fifty third grade students finish an exciting day at the museum. But the bus isn't there. Thirty fifth grade students arrive at the science center, with only the teacher as supervisor. A teacher calls the local nature center, "We would like you to teach our students about animals. We'll be there next Tuesday. There will be 120 second graders." Seventy-five fourth grade students invade a favorite fast food restaurant. . . . nannounced. A student falls and breaks an arm.

Using community resources such as science centers, zoos, or local businesses can provide very meaningful enrichment to a child's education. Doing this allows access to resources not available in most classrooms and gives students the chance to make connections between what they are studying in the classroom and the broader, "real world." However, education in non-formal settings requires planning and consideration of several factors not always part of typical lesson planning.



Planning and Problems

Over many years of planning and observing field trips we have observed that problems during field trips frequently occur in such areas as transportation, safety, interpersonal squabbles or poorly defined educational objectives. For planning purposes, we have found it convenient to categorize these as Logistical Planning, Interpersonal Planning and Technical or Content Planning. By making checklists and outlines of the planning considerations in each of these areas, specific, frequently occurring problems can be avoided.

One person can usually oversee the planning for short field trips involving a single class for a day or less. However, when the field trip involves multiple classes and greater distances or lengths of time, dividing the planning responsibilities between a group of people facilitates more thorough planning. However, if the planning is being divided between several people, it is essential each person has a clear picture of what his/her responsibilities are. Again, this is where checklists or tables are helpful. Essential planning items can be identified with who is responsible.

Planning the Trip

It is essential for teachers to actually visit potential field trip sites before taking a class there. This visit is not only essential for evaluating the educational potential of the site, but can be used to determine the more mundane things, like where are the rest rooms and what is the best route to the site. Never assume the bus driver knows the way. Completing a Resource Inventory Worksheet as described earlier in this chapter will help in the evaluation of the site and planning the field trip.

After the site visit the actual planning begins. The planning includes consideration of all three areas of consideration - logistical, interpersonal and content. *Logistical considerations* include contacting site personnel, transportation, meals, medical emergency procedures, cost estimates, time-lines and supervision. *Interpersonal considerations* include such things as pacing of the trip and how will students be grouped during the trip. More specific considerations are included on the sample check lists at the end of this section. *Content considerations* of the trip include what are the specific objectives of the trip, how will the trip be integrated into the overall instructional program, what will the students be responsible for while at the site and what pre and follow-up activities will be done to maximize the value of the trip.

When planning the trip, it is essential the field trip be task oriented. A simple excursion outside the classroom can rarely be justified as an effective use of time and resources. It is up to the instructor to provide the parameters needed to insure success. The task may be one of several types. It can involve a student-generated description of something. It can involve investigating and answering one important question in depth. It can involve some sort of inquiry which demands problem-solving skills be applied. Or it can involve a survey that necessitates the use of an instrument students have prepared in advance for collecting specific on-site data.

If the instructor is taking the class on a trip to the landfill, for example, students may be assigned an additional task of observing litter/illegal dumping along the route to the landfill. Or, if the trip is to an excellent example of the dominant ecosystem in the region, the instructor may ask students to take notes enroute on the ways in which humans have modified this biome. Thus, even transportation time can be used effectively if arrangements and expectation are established with this in mind!

Above all it is critical that the field trip be incorporated into the overall instructional program. Field trips can be exciting kickoffs to a unit, used to stimulate interest. They can be used in the middle to emphasize specific points. Or, they can be used near the end of a unit to emphasize key concepts or tie together concepts and skills from a range of subjects. In all instances there must be pre and post trip integration, clear expectations both for behavior and educational products and planning by the teacher.

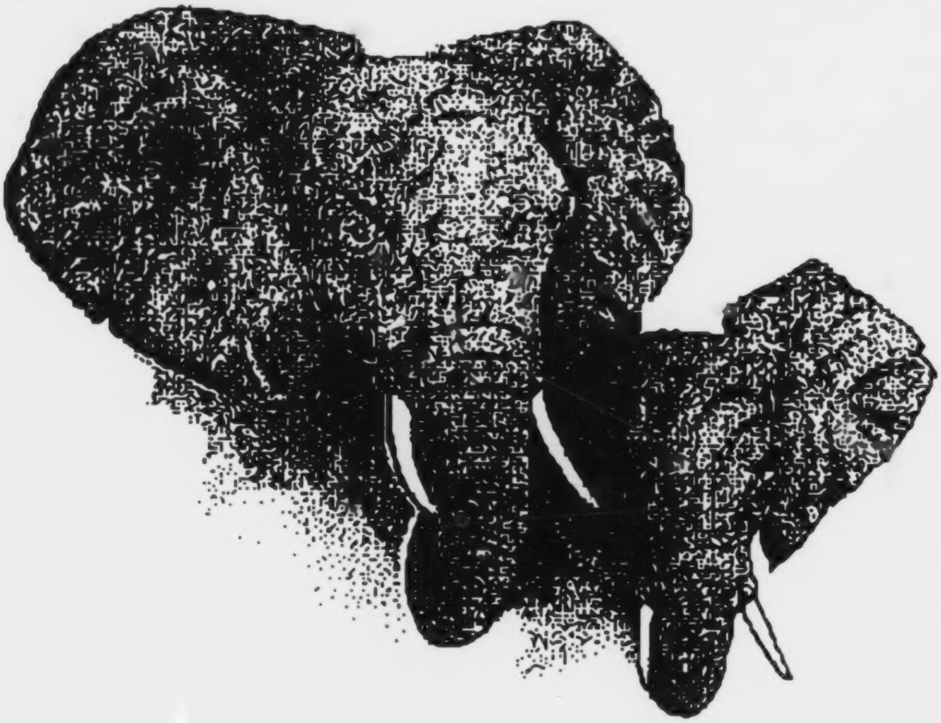
The Assignment

Planning a Field Trip

At the same time you may be asked to visit a potential field trip site. After the site visit and planning considerations have been discussed, you will probably be asked to plan the field trip. The plan should include a transportation plan, cost estimates, supervision and other logistical considerations such as meals and medical emergencies. You would develop a general, overall lesson plan for what children will be responsible for during the visit to the center. What is the general theme and purpose of the field trip? What content areas will be integrated into the learning? Where in the "unit" do you envision using the field trip? The plan should include objectives, handouts, student responsibilities, group size and provisions for supervision. Also, identify and describe classroom activities that may be conducted before and after the trip. How will you evaluate student learning? The emphasis should be on integration of the trip into the ongoing, classroom instruction, not just an out of school excursion.

Resource Inventory

You may also be asked by your instructor to identify a number of resource sites that would be appropriate for field trips and the preparation of a Resource Inventory Sheet for each site.



The zoo can be a wonderful place for a field trip, but it should be visited only with very careful planning!

Variables Controlling Field Trip Planning Considerations

Logistics:

- *Transportation*
  - *When*
    - *Date*
    - *Departure*
    - *Return*
  - *Destination*
    - *Directions*
  - *How*
  - *Cost*
  - *Contact person*
  - *How many people*
    - *Grouping*
    - *Buddy/peer responsibility*
  - *Trip time*
    - *Will a bathroom break be necessary?*
- *Parent permission*
- *Medical/liability release*
- *Accident insurance*
- *Emergency plan*
  - *Prevention measures*
  - *Location of medical facilities*
  - *Notification of administration*
- *Emergency contact*
  - *On trip*
  - *At school*
- *Meals*
  - *When*
  - *Where*
  - *What*
  - *Cost*
  - *Who pays for meals*
- *Total trip cost*
- *Who pays for trip*

Interpersonal:

- *Group size*
- *Duration*
- *Special considerations*
  - *Known conflicts*
  - *Special needs individuals*
- *Group building*
- *Conflict resolution*
- *General courtesy*
- *Stress points within trip*
  - *Food*
  - *Return trip*
- *Set/beginning*
- *Closure*

Technical/Content:

- *Objectives*
- *Skills*
  - *Academic*
  - *Special*
- *Special equipment*
- *Student responsibilities*
- *Evaluation*
- *Safety considerations*
- *Articulation/integration with before and after activities*
- *First Aid Kit*

The Incidental Science Experience (I.S.E.)

The word incidental is defined as being an undesigned feature of something; casual; of secondary importance; accessory. Therefore, an incidental science experience (I.S.E.) might be defined as a casual or undesigned happening related to science instruction in the classroom. Of particular importance is that it need not be of secondary importance. Indeed, for certain purposes the incidental science experience can be extremely important.

What might constitute an I.S.E.? A wide variety of possibilities exist. A child may bring a sack of sea shells to class after a visit to the Gulf coast. A meteor might flash across the night sky and receive wide publicity. An animal might have babies during class time (this has happened more than once). An experiment or demonstration might take a very unplanned turn of events. This could certainly be considered as an incidental (and perhaps unwanted) experience. The teacher might even plan certain "incidental science experiences" for certain students or groups of students.

Many, many opportunities exist for capitalizing on young learners' experiences within or beyond the classroom. An evening spring storm might prompt children to want to talk about it when they get to school. This would be just one more wonderful opportunity to use the youngsters' own experiences as capital for the science program. Photo courtesy H. R. Hungerford.

One very pertinent factor regarding incidental experiences is that they provide high motivation as children seem to be intensely interested in many things that seem discrepant to the normal routine of the classroom. To fail to take advantage of such high interest moments seems unrealistic. They are often the most "teachable" moments.

Few science educators would propose that the I.S.E. be allowed to substitute for a science program that has substance, scope, and sequence. And yet, for certain groups such as culturally deprived children, the incidental experiences, at the primary level particularly, may be of as much value as a more sophisticated science program if used persistently and intelligently. Regardless of the teacher's philosophy, it appears pertinent to explore the values of the I.S.E. so that greater use can be made of it in the classroom.

What will the I.S.E. do for the education process? *First*, as noted before, they provide an opportunity almost without equal for broadening the experiential backgrounds of children. Many students with very limited experiences with their environment should profit tremendously from this strategy. There should be impact for other content areas, as well (e.g., reading, language arts).

Second, the I.S.E. will provide content of high interest for use in language arts. The use of experience charts in conjunction with incidental science experiences has been used often with *outstanding results*. Similarly, writing skills can be practiced with little concern for having to motivate children to tackle the assignment. Many experiences find children searching for more information—going to the library to "look things up" or finding someone who has more information to ask for help. Possibilities are numerous.

Third, some kinds of incidental experiences find students involved in actual science research that would never have taken place without the opportunity provided by the I.S.E.

One Very Interesting Example of a Powerful I.S.E.

Some years ago one of the writers of this text had a student teacher in the middle school who had occasion to set up what is some times referred to as the "Pasteur Spontaneous Generation Experiment." The demonstration is a relatively simple one consisting of five flasks, each containing a nutrient broth in which microorganisms can flourish. In turn, each of these flasks is exposed to the air in a different way using one-hole rubber stoppers and glass tubing. Three of the flasks are set up so that spores in the air can get into the broth and begin growing. Two of the flasks are stoppered so that spores cannot get into the broth. If spores get into the flasks the change in the broth is dramatic within a few days. There can be no question about whether something is going on inside. Both eyes and nose collect information to verify this.

The student teacher set up the demonstration, gave specific instructions to students to carefully observe all flasks, and was horrified to find that growth was taking place in flasks where no one expected mold or bacteria to be found. He came to the writer in near panic to implore him to suggest some way to salvage his demonstration and his pride. It was suggested, since every student was aware of what had happened, that he squarely face the problem with the students and admit something had gone wrong. Also, it was suggested that he explain how the demonstration has been set up so that the students could conceptualize the process. Then, he might ask the students to hypothesize reasons for the failure of the demonstration and to come up with an alternative method of setting it up so it could be tried again, this time with student help. Pride wounded, the student teacher did all of these things. To his great surprise, the students respected his honesty, seriously approached the hypothesizing, and enthusiastically entered into the work involved with setting up a duplicate experiment. The next time there was no failure, and when the student teacher left the writer's jurisdiction, he admitted that this had been his most profitable lesson as a student teacher—for him and for the students. Indeed it was, and it was the direct result of an I.S.E.

One of the concerns of many elementary teachers is their own knowledge about science. There are those teachers that adamantly refuse to cope with an I.S.E. because they feel so inadequate in the affairs of science, particularly unexpected situations like those in question. This is hard to understand because the knowledge in science is so substantial that *no one* has *all* the answers. Students who are naturally curious about an object or event are also usually quite willing to research it and report to all concerned (including the teacher). To fail to grasp a classroom situation ripe with positive educational potential seems somehow unethical and, at best, in poor judgment.

How long should a teacher persist with the use of an I.S.E. for purposes of instruction? Certainly, it seems unwise to use it for a period longer than motivation exists. Let the children satisfy their curiosity and then move on. If other than this is done, the students may find their curiosity suddenly repressed if they anticipate only hard work and drudgery as a result of expressed interest.

Earlier the point was made that incidental science experiences have value for the language arts. Reference was made to experience charts. Let us take a look at a couple of examples that actually originated in University School at Southern Illinois University. The first is the result of a walk taken by first graders on a warm day in autumn. Many things were observed, and upon returning to the classroom some of these were recorded by the students via the experience chart method. The prose elicited from the children follows:

OUR FALL FIELD TRIP

We went on a fall field trip.
We were looking for signs of fall.
The leaves have changed colors.
We saw red, yellow and yellow-green leaves.
Some of the trees were bare.
Patty found some tiny leaves of different colors.
We found some milkweed.
Milkweed seeds fly in the fall.

In that same first grade classroom, the students "discovered" fossils one day at recess in the rocks that formed a wall on one side of the school building. They literally buzzed with excitement. The teacher saw a golden opportunity to capitalize on this event and make it into a very productive science experience. She sought out the writer and borrowed several dozen fossils. The children inspected these and made pencil rubbings of those that were fairly flat. She then asked a geologist to come in and talk about fossils with the children. He sat on the floor with the youngsters and told them many interesting things about the fossils they had in the room.

Lastly, she found a sound filmstrip on fossils and showed it to the children. Subsequent to all of these experiences she wrote a language experience chart as the children dictated it to her. She confided to the writer later that the children wanted to use the word "paleontologist" in the story but that she didn't do it because she couldn't spell it. Remember, these were first graders. When asked whether the children would have been able to read an experience chart with that kind of vocabulary, she unhesitatingly responded, "Of course!" When *produced* by the children in this format, the prose can be *read by* the children. Somehow that seems like a very useful principle to remember. The "Fossils" experience chart follows:

The first grade teacher confided in the writer that the children wanted to use the term "paleontologist" in their story but she couldn't because she didn't know how to spell it!

FOSSILS

We found some fossils in the rocks on the playground. Fossils are very old. It takes thousands of years for fossils to be made.

There are many kinds of fossils. Some are plants and some are animals. They are the marks left in rocks after the plants and animals died. Fossils are formed in many ways. Scientists study fossils to learn about the plants and animals that lived long ago.

If children are hesitant to volunteer their own incidental science experiences, the teacher should encourage them to do so and to share their enthusiasm and findings with fellow students in the classroom. It can be handled much like the "show and tell" technique so often used by primary teachers. If this strategy fails, the teacher should not hesitate to "stack the deck" and provide highly motivational events until the students begin responding with their own. A gerbil or pair of gerbils can be extremely motivational in any classroom, K-8. What child fails to be interested in a box turtle? The thrill of using a high-powered microscope (borrowed from the local biology teacher) to peer at tiny organisms is apparent at almost any age. Why not invite a pilot to drop by for a classroom visit?

The I.S.E. - In Summary

Incidental science experiences are ones that are of immediate concern and have usually been unplanned. Many incidental experiences can be anticipated in the elementary school. They are highly motivational. Incidental experiences can provide a rich source for broadening experiential backgrounds in science. Similarly, they have great potential as vehicles in language arts instruction. Teachers should not be reticent about using an I.S.E. because they are fearful of their own inadequacies.

Incidental Science Experiences are highly motivational and provide a rich source for both science and language arts!

Examples of Other Opportunities to Supplement the Textbook

What do you do when the materials in the textbook are not enough? Maybe the book doesn't provide enough experience for the students to develop the concept or you want to try to integrate material across the curriculum. When these things happen, there are a number of choices. You can stick with the text and do without the enrichment. You can create the new lessons, using your own creativity. Or, you can look at supplementary resources and adapt them to your specific needs.

There is a wealth of material available for teachers from which to draw as they try to enrich their curriculum. Some of these are free or inexpensive from agencies, private organizations, or industry. Others can be purchased from bookstores or through professional organizations. Professional journals such as *Instructor, Science and Children* and *Science Scope* are excellent sources of ideas for specific lessons as well as names and reviews of supplemental material. Other materials such as old magazines or seashells collected while on vacation may be lying around the house just waiting to enrich your teaching.

Regardless of the source, teachers need to be selective in bringing in outside material into the classroom. Much of the material available is excellent and appropriate for use by teachers. However, some is clearly "propaganda" and is more concerned with delivering a specific message, or selling a product than in educating children.

The authors suggest considering the following points when considering including material in the classroom:

1. Will the material help meet defined educational objectives?
2. Does the material or activity "fit" into the curriculum, replace activities or is it simply an "add on"?
3. If the material or concept is an "add on," what will be omitted or reduced in depth to make room for the additional material?
4. Is the material developmentally appropriate?
5. Are there obvious or hidden racial, cultural, or gender biases - or are there factual errors?
6. Is the material trying to sell or promote a particular product or promote a particular organization?
7. Is the material trying to promote a particular belief or behavior? If the answer is "yes," is this belief consistent with your educational goals or will alternative views need to be presented?

Watch out for number 6 and 7! These problems do exist and they are often very subtle, and hidden beneath the gloss. Carefully review any "add-on" supplementary resources before using them with students. In this case "free" does not mean problem free.

Examples of Supplemental Material

There are many examples of supplemental materials available from which the teacher can draw. Some of these are designed as units that are intended to be inserted into the curriculum. Others are either single activities or collections of activities that teachers can pick from and choose to meet specific needs. This second group of materials are probably the most widely available and allow teachers to use activities to strengthen specific facets of their curriculum without adding whole new areas.

In the life sciences, three of the most widely used sets of activities are *Project WILD*, *Project Learning Tree* and *Outdoor Biology Instructional Strategies (OBIS)*. Each of these has its particular strengths. Thoughtful selection of activities from any of these collections can greatly enrich the instruction in the elementary classroom.

Project WILD and Project WILD Aquatic

Project WILD and *Project WILD Aquatic* are collections of interdisciplinary, environmental and conservation education activities designed to supplement an already prepared curriculum. Together the two books include over 150 activities. The activities are designed to be infused into the curriculum and help teachers meet existing goals and objectives in several disciplines including language arts, social studies, art and mathematics as well as science.

> **The goal of *Project WILD* is to assist learners of any age in developing awareness, knowledge, skills and commitment to result in informed decisions, responsible behavior and constructive actions concerning wildlife and the environment upon which all life depends.** (This goal statement taken from *Project WILD* materials.)

Activities in *Project WILD* use wildlife as a theme to try to accomplish this goal. This theme has been shown to spark interest in students. It is also important for students to learn about the basics of wildlife and the interrelationships that exist between all life. *Project WILD Aquatic* activities use the water environment and aquatic wildlife as a unifying theme to accomplish the same goals.

The activities in each book are arranged around seven major themes with up to 10 to 24 activities supporting each theme. The seven themes are:

Awareness and Appreciation of Nature
Diversity of Wildlife Values
Ecological Principles
Management and Conservation
People, Culture and Wildlife
Trends, Issues and Consequences
Responsible Human Actions

Each of the activities is presented in a similar format. The components of each lesson include:

Title
Subject Areas
Concepts
Skills
Variations
Evaluation Suggestions
Materials
Age/Grade Level
Setting
Objectives
Extensions
Group Size
Instructional Method
Key Vocabulary
Duration
Procedure
Background Information

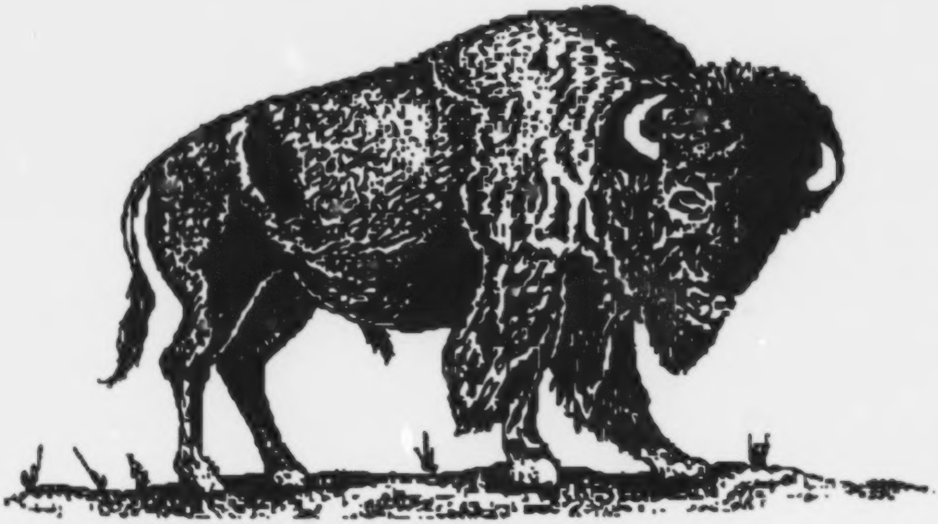
Of particular value to the teacher is the background information provided for the key concepts presented in the lesson. The information will not make you an expert on the subject, but is generally adequate enough to get started. Many teachers that use *WILD* activities set up folders for the activities frequently used, and clip articles to add to the background information.

Another useful feature of the books is the extensive appendices provided. These appendices include a Glossary, Guidelines for Using the Outdoors as a Classroom, as well as indices that cross reference the activities by Grade Level, Major Concepts, Indoor vs. Outdoor, Skill Development and an Alphabetical Listing.

The "Suggestions for Evaluation" provided with each activity are particularly useful for teachers using different forms of authentic or performance based assessment. The suggestions provide examples of ways students can demonstrate their ability to apply the concepts and skills developed during the activity beyond traditional paper/pencil test formats.

Research on the effectiveness of *Project WILD* suggest the activities are effective in introducing students to the major concepts of ecology and wildlife. They are also effective in introducing issues related to wildlife and resource conservation without providing answers to those issues.

Project WILD is available free of charge in all 50 states. However, the books are only available through participation at a training session. These trainings are usually offered by the Department of Natural Resources or the equivalent agency in conjunction with local sponsoring agencies such as school districts or colleges. Contact the Information and Education office of the Department of Natural Resources or equivalent agency in your state for additional information.



Project Learning Tree

Project Learning Tree : The Environmental Education Activity Guide (PLT) is similar to *Project WILD* except that it is much broader in scope in selection of activities. *Project Learning Tree* activities cover the range of environmental education from basic ecological foundations to responsible decision making skills. There is no central theme linking all activities as in *Project WILD and WILD Aquatic* but as the name implies, there are many more activities using trees and forests as their focus. Originally all of the activities were based on trees and forests, but the most recent revision, completed in 1993, expanded the activities to include the full range of environmental education.

Like *Project WILD*, PLT activities are multi-disciplinary in nature. Most activities are designed to include knowledge and skills from several different disciplines while developing a concept associated with environmental education. These concepts range from basic ecological principles to sensory awareness to skills necessary to help resolve an environmental issue. A more detailed discussion of the goals of Environmental Education is provided in Chapter Ten.

The goals of *Project Learning Tree* are to:

1. . . . provide students with the awareness, appreciation, understanding, skills and commitment to address environmental issues;
2. . . enable students to apply scientific processes and higher-order thinking skills to resolve environmental issues;
3. . . . help students acquire an appreciation and tolerance of diverse viewpoints on environmental issues, and develop attitudes and actions based on analysis and evaluation of the available information;
4. . . . encourage creativity, originality and flexibility to resolve environmental problems and issues;
5. . . . inspire and empower students to become responsible, productive and participatory members of society.

With these goals in mind, teachers must remember, PLT is not a curriculum. It is a collection of activities that you as teachers will need to sequence and weave into your instructional program. No one activity will accomplish all of these goals, just as no one lesson accomplishes any other educational goal.

The authors of PLT have grouped the activities into five major "Themes." The five Themes are:

1. **Diversity**: Throughout the world, there is great diversity of habitats, organisms, societies, technologies and cultures.
2. **Interrelationships**: Ecological, technological and socio-cultural systems are interactive and interdependent.
3. **Systems**: Environmental, technological and social systems are interconnected and interacting.
4. **Structure and Scale**: Technologies, societal institutions and components of natural and human-built environments vary in structure and scale.

5. **Patterns of Change**: Structures and systems change over various periods of time.

Each of these themes of activities is subdivided in "Storylines" made up of four to six activities. These Storylines present groups of activities that may be readily sequenced into a series of lessons. Teachers report this feature makes weaving PLT activities into the rest of their curriculum much easier.

The design of the activities in PLT is based on the constructivist learning theory and whole language learning teaching strategies. Constructivist theory suggests students must build their understanding of the world from their experiences. PLT activities are designed to promote this understanding through meaningful, integrated lessons that let students experience their world. PLT activities are also designed to help promote more involved, responsible citizens through building a foundation of ecological knowledge and awareness of issues as well as attempting to develop the skills necessary to take responsible action.

Project Learning Tree is available in all 50 states. The activity books may be obtained by participating in a one-day training. Contact the Education and Information Office of the Department of Conservation or equivalent agency in your state for additional information.

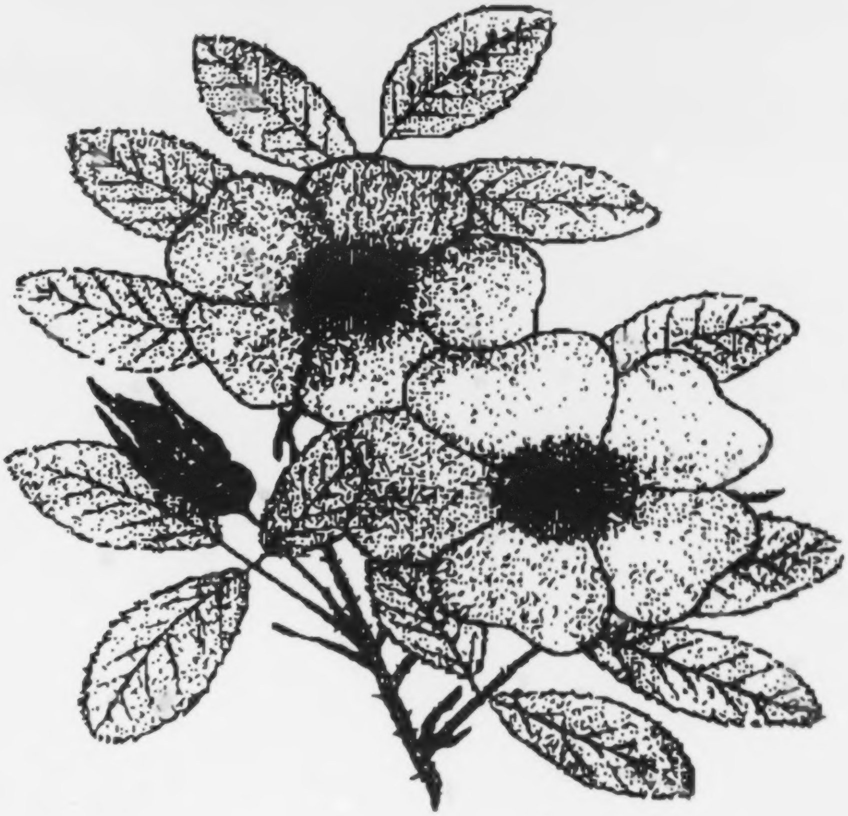
Outdoor Biology Instructional Strategies (OBIS)

OBIS is a series of lessons designed to help teachers effectively use the outdoors as part of their classroom. Originally designed for use by naturalists at nature centers and leaders of youth groups such as Boy Scouts and Girls Scouts, many teachers have found OBIS activities excellent resources for teaching basic biology concepts on their own school grounds. As you may have gathered from earlier parts of this chapter, the authors strongly encourage you to use resources outside the classroom. Students need to get out of the classroom and learn about the ecosystems and history where they live.

OBIS is divided into four sets of activities that cover a range of habitats from school yards to forests and ponds. Each set contains 10 to 15 folios of activities. Each folio contains a sequence of activities that develop a specific concept such as adaptation, or food chains. Doing all of the activities in a single folio will take most classroom teachers several days unless a major portion of the day is devoted to the activity.

The activities seem to be well designed. Minimal special equipment is needed. A hand lens and sweep net are about as "high tech" as the equipment gets. Each activity includes procedure, safety guidelines, and suggestions for discussion questions. However, background information on the specific topics is limited.

Sets of OBIS materials are available from: Lawrence Hall of Science, University of California, Berkeley, CA 94720



Chapter Ten

Understanding and Teaching Environmental Education (EE)

Environmental education is a process that leads to responsible individual and group actions. . . . Environmental education should enhance critical thinking, problem solving, and effective decision-making skills. . . . Environmental education should engage and motivate individuals as well as enable them to weigh various sides of an environmental issue to make informed and responsible decisions.

EPA Environmental Education Grants Solicitation Notice
Federal Register, Friday, October 16, 1992. p 47516.

Following your interactions with this Chapter, you will be expected to be able to…

1. … pose a valid definition for environmental education (EE) and be able to defend it from an educational perspective.
2. … explain why EE involves issues, human beliefs, values, and natural resources.
3. … define "environmental literacy", and communicate a rationale for the importance of EE in elementary and middle schools.
4. … discuss, in depth, the literacy attributes (outcomes) found under each literacy component and the reasons why these outcomes are important for students.
5. … describe what is meant by the "infusion model" for EE and how EE might fit into existing elementary and middle school courses. Further, a rationale for using the "infusion model" should be communicated.
6. … identify the variables associated with environmental literacy as described in the worktext. These are: (l) knowledge of issues, (2) beliefs, (3) values, (4) attitudes, (5) locus of control, (6) sensitivity, (7) environmental action, and (8) ecological knowledge (concepts). Further, be able to communicate why each of these variables is important for achieving literacy.
7. … discuss the importance of having students investigate and evaluate environmental issues. Also, be able to communicate important educational objectives associated with issue investigation (i.e., skills needed to successfully investigate issues).
8. … list and define the five environmental action categories.
9. … list the two major levels of environmental action, and state which is usually more effective and why it is more effective.
10. … list at least ten of the fourteen questions that should be answered before an environmental action is decided upon. Further, the importance of answering each of these questions should be described.

An Example of Environmental Education in the School

This fictionalized account describes a skilled and informed citizen successfully prepared to deal responsibly with science-related environmental issues using sound instruction in environmental education.

"Recently, my community became embattled over what should be done to remedy the serious problems associated with solid waste disposal. My own involvement with the issues that surrounded this problem give me pause to remember my public school science and environmental education instruction. I most certainly have to acknowledge the value of the instruction that I received during elementary, middle, and secondary schools. Although I didn't always appreciaie it, my teachers pushed and shoved me toward the 21st century as a community member who understood issues like this one and someone who felt comfortable becoming involved in this issue.

Although I can't put my finger on the one thing in my schooling that helped me, I can certainly look back and see a number of things that, together, helped make me the kind of a citizen I am today.

Importantly, I was taught environmental issue investigation and resolution skills. I can remember one of my middle school instructors - Ms. Conway - explaining that science-related environmental issues were fluid kinds of things, that they didn't remain static. She stressed that, in order to cope successfully with these issues, citizens needed to . . . understand the anatomy of issues; know how to obtain reliable information about issues, how to interpret that information, and how to go about making personal decisions concerning that information; and be able to translate those decisions into overt citizen behavior.

At first this didn't make much sense to adolescents but, by golly, she had a way with all of us. After we learned the skills associated with issue analysis and investigation, Ms. Conway gave us the toughest assignment of our early years - investigating a science-related social issue of our choice and reporting back on it. That experience gave me a sense of "ownership" of that issue. I can still remember being the only student in that class with expertise on that particular issue. And, Ms. Conway was quick to point out that I knew more about that issue than she did. She also said that to a number of the other students. Now that really made us feel good!

After we were finished with our issue investigations, Ms. Conway told us that there was still another step involved in the issue business. She told us *that it wasn't enough to be an expert on issue investigation, we also needed to know how to resolve issues. She joined forces with the social studies teacher and, together, they spent considerable time helping us understand strategies like consumer action, political action, legal action and others. They then set out to give us some of the skills associated with these kinds of citizenship strategies. One might think that it ended there but it didn't.*

After getting all of this information about and skills associated with citizenship action, we were asked to go back to the issues of our choice and lay out an "action plan" for helping solve the issue. That should have done it, right? But, no, that still wasn't the end. Once we had an action plan laid out, we had to evaluate that plan against a set of criteria that included things like the social, economic, political, and ecological consequences of our proposed action. If our plan indicated that it might do more harm than good, we had to revise it. It wasn't easy! But, the more I worked with a strategy for helping to resolve my issue, the more "empowered" I felt. I wanted to do something about that issue more than ever. Interestingly, Ms. Conway told us that it would be up to us to decide if we wanted to put that action plan into effect. She said she would support us either way.

To make a long story shorter, when solid waste became a pressing problem in the community, I set about to get as informed as possible about the issues. I learned who the "players" were and what they believed, and I tried to infer the value perspectives behind those beliefs. I investigated the pros and cons of various forms of waste management until I felt comfortable with the information. I then took a hard look at our community and its environment and tried to make some rational decisions about the best way to resolve that problem in our particular community.

When a hearing was posted for the problem, I decided that it was important to be there. I just had to be heard. I didn't want political or economic values to override ecological ones. When I arrived at the hearing I looked around and saw several of my classmates. It dawned on me that we should have formed a citizens' coalition up front. I'm still amazed that somebody from our class didn't get on the phone and organize that coalition. Still, it didn't seem to matter too much because those of us that were there had made pretty much the same decisions regarding the problem and, when we had been heard, I think that we helped move city government toward a responsible decision concerning the problem.

So, for me, and for a large number of my classmates, our schooling worked. My own kids are in school now and I hope that they will get the same instruction that I did. Fortunately, Ms. Conway is still teaching. I hope she's still there when my own kids get there."

A FEW OF THE ISSUES ASSOCIATED WITH THE ENVIRONMENT

In some places on our planet we still discard our garbage into our environment and burn it. Some think that this is an ugly practice and results in aesthetic pollution. We do know, however, that this can contaminate both surface and ground water as well as pollute the air. Photo courtesy H. R. Hungerford.

FOR SALE
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LOTS
687-1633
684-4540
568-1131

In other places on our planet we try as we might to sell our environmental heritage. Poor land-use management practices are said by some to be one of the top three environmental issues facing humans today. The land in this scene was a productive apple orchard before it was bulldozed for development. Photo courtesy H. R. Hungerford.

More land-use issues arise as natural ecosystems are converted to farm land and then to towns and then to cities. Human needs associated with subdivisions, highways, railways, airports, factories, and other artifacts of the built environment create a myriad of problems and then issues. Photo courtesy H.R. Hungerford.

In still other places on our planet we introduce exotic species which enjoy few checks and balances in their new environments. Here kudzu grows over and crowds out the native vegetation in western Kentucky. Awful things have also happened in the U.S. with multiflora rose, Japanese honeysuckle, English sparrows, starlings, and numerous other species. Photo courtesy T. L. Volk.

We also manage to kill off our fellow creatures at an alarming rate. This iguana is endangered in Mexico. Why? People searching for protein have found that it is delicious and in some places iguanas have simply disappeared. Photo courtesy T. L. Volk.

In an effort to exercise control over our environment we do strange things like channelize rivers and put enormous levees on the sides of them to make sure that they do not flood communities and farms placed on flood plains. Sometimes this doesn't work which was dramatically demonstrated early in this decade in the Midwest. Photo courtesy H. Hungerford.

Understanding and Teaching Environmental Education (EE)

What IS Environmental Education (EE)?

Environmental education (EE) can be a confusing term. In fact, it is sometimes easier to tell what it isn't than what it is. The term, EE ,has been used by outdoor educators, conservation educators, nature interpreters and many others as an umbrella under which to house their own activities. Sometimes it seems as though EE is all things to all people. Unfortunately, if this is true, little will be accomplished with it. What, then *is* EE?

The answer to this question lies, in large part, in a conference held in Tbilisi, Russia in 1977. This conference was sponsored by Unesco-UNEP (United Nations Environmental Program). Representatives from over 100 Unesco member nations attended this conference. The conference was designed to produce a document that would establish boundaries for EE and try to get the nations of the world involved in the teaching of EE (in the world's communities in general). The Tbilisi conference produced a set of five objectives for EE which focused on five areas of environmental education concern. These five objectives were: (1) environmental awareness, (2) environmental knowledge, (3) attitudes, (4) environmental skills, and (5) citizen participation in the resolution of environmental problems.

If we look once again at a slightly revised definition found in the EPA Environmental Education Grants Solicitation Notice (1992) we find that most of the five Tbilisi components are reflected in it. Environmental awareness is certainly inferred as you shall see later on in this chapter. This definition means that environmental education must be issue oriented, and that it should be responsible to the development of those skills and attitudes that motivate human beings to make responsible decisions in the resolution of environmental issues.

Environmental education is a process that leads to responsible individual and group actions. It should also enhance critical thinking, problem solving, and effective decision-making skills. In addition it should also engage and motivate individuals as well as enable them to weigh various sides of an environmental issue to make informed and responsible decisions.

So What? Why Should We Bother With EE?

Rationales for EE in the schools are many - although we do not currently see EE as a major part of the elementary school. A few states have passed legislation making it mandatory to teach EE. Other states have carefully developed goals and objectives for environmental education (e.g., Missouri, Maryland, Wisconsin, Hawaii). As this is being written, others are in the process of preparing goals and objectives (e.g., Illinois). The writers suggest that EE should be taught throughout the elementary and middle school simply because it is a terribly important part of the curriculum.

Evidence for the crucial importance of EE can be found in many documents or articles produced by many agencies and individuals. Let us simply refer to the *Global*

2000 Report to the President of the U.S. "Global 2000" is documentation of a study ordered by President Carter in 1977 that was printed in 1979. The purpose of this study was to seriously explore critical environmental issues on a global basis and to predict the status of these issues in the year 2000. The responsibility for putting the report together went to the Council on Environmental Quality. The study's director was Gerald O. Barney, a recognized expert on population, resources, and environmental issues.

The Global 2000 Report to the President of the U.S.—Entering the 21st Century—Volume 1. The Summary Report was published by Pergamon Press (New York) in 1980. The authors of your methods text feel that a few statements taken from this document support the contention that EE is a critical component in a youngster's education. These quotes follow (all taken from Part 1—Major Findings and Considerations):

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutionary advances in technology, life for most people on **earth will be more precarious in 2000** than it is now—unless the nations of the world act decisively to alter current trends....

Global 2000 stated that life on earth would be more precarious at the turn of the century than it was two decades earlier - unless the nations of the world would act to alter existing trends.

> Rapid growth in world population will hardly have altered by 2000. The world's population will grow from 4 billion in 1974 to 6.35 billion in 2000, an increase of more than 50 percent. The rate of growth will slow only marginally....
>
> While the economies of the less developed countries (LDCs) are expected to grow at faster rates than those of the industrialized nations, the gross national product per capita in most LDCs remains low. The average gross national product per capita is projected to rise substantially in some LDCs (especially in Latin America), but in the great populous nations of South Asia it remains below $200 a year (in 1975 dollars). The large existing gap between the rich and poor nations widens.
>
> World food production is projected to increase 90 percent over the 30 years from 1970 to 2000. This translates into a global per capita increase of less than 15 percent over the same period. The bulk of that increase goes to countries that already have relatively high per capita food consumption. Meanwhile per capita consumption in South Asia, the Middle East, and the LDCs of Africa will scarcely improve or will actually decline below present inadequate levels. At the same time, real prices for food are expected to double.

Even though Global 200 was written almost two decades ago, it still exists as one of the most important environmental documents of our time. Predictions made then have proven to be amazingly correct.

> Arable land will increase only 4 percent by 2000, so that most of the increased output of food will have to come from higher yields—fertilizer, pesticides, power for irrigation, and fuel for machinery—depend heavily on oil and gas.

> For the one-quarter of humankind that depends primarily on wood for fuel, the outlook is bleak. Needs for fuel wood will exceed available supplies by about 25 percent before the turn of the century . . . .

> **"The world faces enormous, urgent, and complex problems in the decades immediately ahead. Prompt and vigorous changes in public policy around the world are needed . . . ."**
>
> ***The Global 2000 Report***

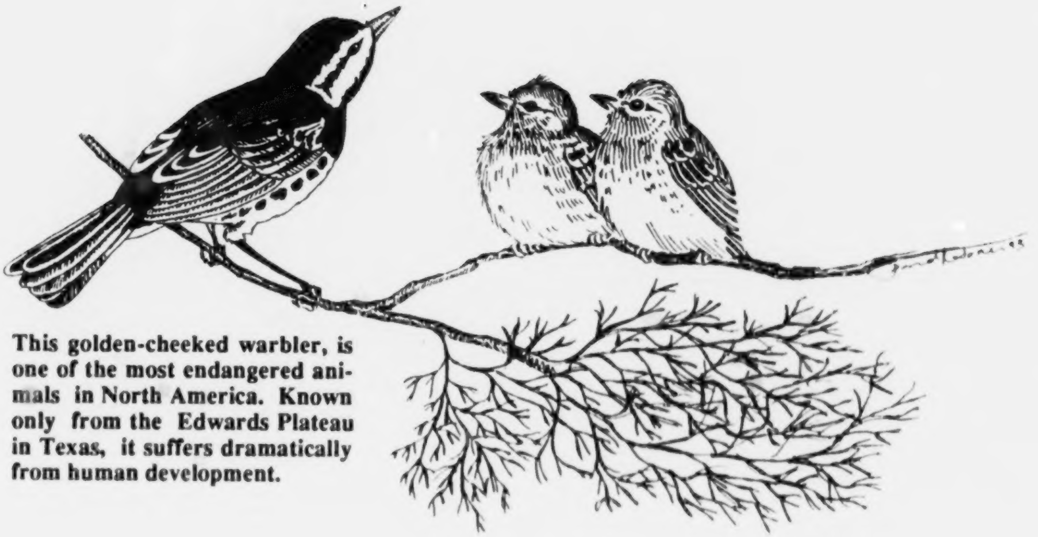
> Regional water shortages will become more severe. In the 1970-2000 period, population growth alone will cause requirements for water to double in nearly half of the world . . . .
>
> Significant losses of world forests will continue over the next 20 years as the demand for forest products and fuel wood increases . . . .
>
> Serious deterioration of agricultural soils will occur world-wide, due to erosion, loss of organic matter, desertification, salinization, alkalinization, and waterlogging. Already, an area of cropland and grassland approximately the size of Maine is becoming barren wasteland each year, and the spread of desert-like conditions is likely to accelerate.
>
> Atmospheric concentrations of carbon dioxide and ozone-depleting chemicals are expected to increase at rates that could alter the world's climate and upper atmosphere significantly by 2050 . . . .
>
> Extinctions of plant and animal species will increase dramatically. Hundreds of thousands of species—perhaps as many as 20 percent of all species on earth—will be irretrievably lost as their habitats vanish, especially in tropical forests.

The future depicted by the U.S. Government projections, briefly outlined above, may actually understate the impending problems.

> Indeed, the problems of preserving the carrying capacity of the earth and sustaining the possibility of a decent life for the human beings that inhabit it are enormous and close upon us.... The available evidence leaves no doubt that the world - including this nation - faces enormous, urgent, and complex problems in the decades immediately ahead. Prompt and vigorous changes in public policy around the world are needed to avoid or minimize these problems before they become unmanageable. Long lead times are required for effective action. If decisions are delayed until the problems become worse, options for effective action will be severely reduced.

The implications of these projections were ominous and remain so today. The issues associated with these projections must be addressed directly and courageously if present and future generations of the world community are to have a quality of life even close to that enjoyed by citizens in developed nations today.

> *The earth as a life-support system is deteriorating. This the reader must understand clearly, in case he hasn't noticed or has been persuaded otherwise. In some respects our children's world will be better than ours, but on balance it will be uglier, less interesting, and more dangerous. This is not a pleasant fact to face, but denial is not a sufficient response to the problem.*
>
> *R. Thomas Tanner*



This golden-cheeked warbler, is one of the most endangered animals in North America. Known only from the Edwards Plateau in Texas, it suffers dramatically from human development.

Well Then, What's The Answer?

The answer to these problems and others may be helped by focusing education on something called "environmental literacy." This term stands for a set of human attributes that would help human beings resolve issues and provide them with the skills needed to cope with future ones.

Earlier, a number of international EE objectives (Tbilisi Conference Objectives) were referred to as setting the stage for defining EE. However, these objectives are far from realized. Knowing this, a team of professionals from Illinois, Wisconsin, and Michigan set about to translate these objectives into goals for curriculum development in EE. These goals were subsequently published in the Spring 1980 issue of the *Journal of Environmental Education.*

From these curriculum goals a set of "Environmental Literacy Components" has been developed. Included in these literacy components is what is referred to as an Overall Literacy Component and four subordinate ones, each with several parts. The "Environmental Literacy Components" are as follows:

Environmental Literacy Components

The Overall Component. The environmentally literate citizen is able and willing to make environmental decisions that are consistent with both a quality of human life and an equal quality of the environment. Also, this individual is motivated to act on these decisions either individually or collectively.

Comments on the Overall Literacy Component:

It should be noted that many people get confused when one speaks of "quality of human life" on one hand and "quality of the environment" on the other. Whether or not a society can have it both ways is really a moot issue. Humans have reached a crossroads in environmental destiny where almost any decision made is seen as a compromise between these two variables. There are simply too many human beings on the face of the earth to maintain either a desired quality of life for all peoples or an environment free of degrading influences. Therefore, environmental decisions somehow compromise people, or the environment, or both. Of course, this leads to all sorts of moral and ethical questions, which will remain unaddressed at this point. The fact remains, however, that "quality of life" and "quality of the environment" must both be seriously considered in any decision making process.

Subordinate Literacy Components: These are the components which exist beneath the one discussed above.

Literacy Component I—Ecological Foundations: At this level, the learner has sufficient knowledge of ecology to permit ecologically sound decisions with respect to both humans and the environment .

Although it is difficult to pinpoint exactly that ecological knowledge which is critical and prerequisite to sound environmental decision making, certain key concepts and allied ecological principles appear crucial. Therefore, the writers believe **that the principles associated with the following concepts** need to be understood in order to permit the application of the principles to environmental decision making.

A. Individuals
B. Population Dynamics
C. Interaction
D. Interdependence
E. Limiting Factors
F. Energy Transfer
G. Biogeochemical Cycling
H. The Community
I. The Ecosystem
J. Homeostasis
K. Succession
L. Man as an Ecological Variable

Literacy Component II—The Awareness of Issues and Human Values: This component, like the previous one, seeks to provide the learner with *information*. Rather than ecological information, however, this component deals with a wide variety of so-called environmental information. Again, it might be said that this information or knowledge is prerequisite to the actual investigation, evaluation, and remediation of issues.

The environmentally literate person then, at this level, understands . . .

A. . .the way in which human cultural activities impact on the environment. Here, cultural activities would include economics, religion, politics, social customs, etc.

B. . . . the way various individual behaviors impact on the environment.

C. . . . a wide variety of environmental issues and both the ecological and cultural implications of these issues.

D. . . . the various alternative solutions available for solving (or partially solving) discrete environmental issues. Of critical concern here would be the ecological and cultural implications of these various solutions.

E. . . . the need for thoroughly investigating and evaluating issues prior to taking environmental action.

F. . . . the roles played by differing human values in environmental issues. Also, an understanding of the genesis of these varying values appears crucial.

G. . . .the need for personal values clarification as an integral part of environmental decision making.

H. . . the need for responsible citizenship action in the solution of environmental issues.

Literacy Component III—The Investigation and Evaluation of Issues and Solutions: This component, unlike the previous two components, goes beyond the acquisition of information per se. Level 111 deals with the development of those skills necessary for the actual investigation and evaluation of environmental issues. Further, it provides for the evaluation of alternative solutions for solving issues.

The environmentally literate person then, at Level III, has those skills enabling him/her to . . .

A. . . .identify and investigate environmental issues using both primary and secondary sources of information.

B. . analyze environmental issues with regard to the various perspectives associated with those issues. Further, the learner is able to identify the ecological and cultural implications of these value positions.

C. . . identify alternative solutions for discrete issues and the value perspectives associated with these solutions.

D. . . . evaluate alternative solutions for discrete issues with regard to their ecological and cultural implications.

E. . . . identify and clarify his/her own value positions related to discrete issues and the solutions proposed for those issues.

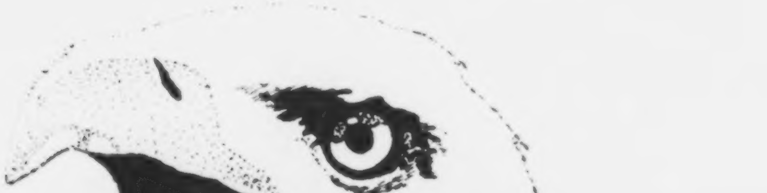
Literacy Component IV—Citizenship Action: This component deals with those skills necessary for learners to take appropriate environmental action.

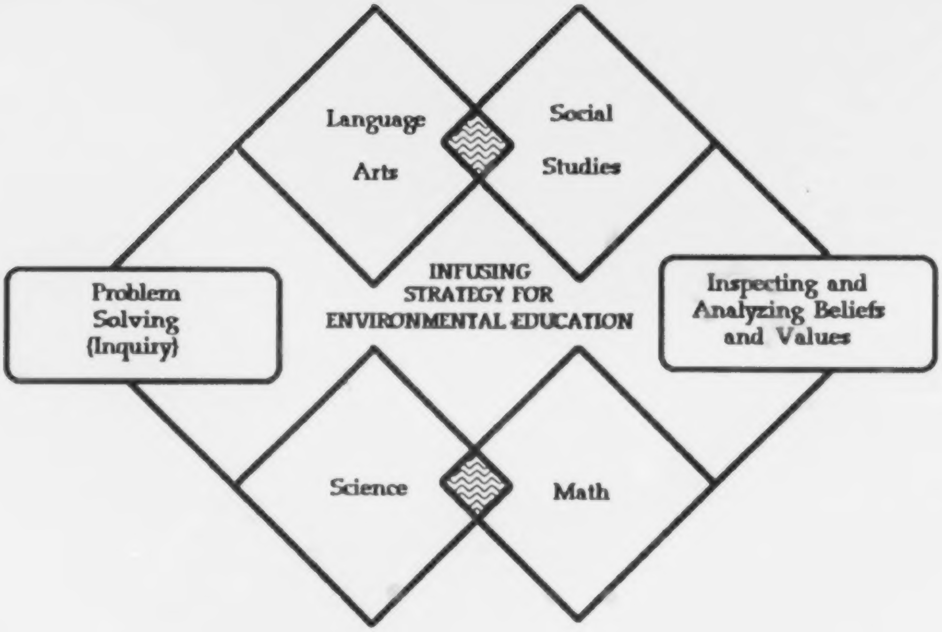
Here the environmentally literate person has those skills enabling him or her to . . .

A. . take either individual or group action (i.e., persuasion, consumerism, political action, legal action, ecomanagement) where appropriate for the purpose of solving or assisting to solve particular issues.

B. . . . evaluate actions taken with respect to their impact on quality of human life and quality of the environment.

Literacy, then, *begins with knowledge and ends with action*. These literacy outcomes are, by and large, hierarchical in nature. However, two or more components or subcomponents can be acquired simultaneously (e.g., certain ecological knowledge and issue knowledge or issue information and the alternative methods of investigating those issues). In fact, to assume that each literacy component or subcomponent must be acquired independently of others is probably educationally unsound. There is far too much overlap between many of them. Thus, environmental literacy outcomes are interdependent and should be learned in a manner which is logical and defensible.




Language Arts
Social Studies
Problem Solving (Inquiry)
INFUSING STRATEGY FOR ENVIRONMENTAL EDUCATION
Inspecting and Analyzing Beliefs and Values
Science
Math

Where Does EE Fit?

A review of the "Environmental Literacy Components" just presented should make it very clear that EE intersects with a number of traditional content areas. Literacy Components II A, C, & H are sharply related to the social studies. Component III A is traditionally a language arts component. Thus, EE does not fit any one traditional discipline. Does this mean, then, that EE should be a separate course in the curriculum?

Although some schools - particularly at the middle school level - offer a separate course in environmental education, most schools find it hard to fit another course into an already crowded curriculum. This results in either forgetting about EE completely (which is often the case) or using what is called an "infusion model." In the infusion model, EE is incorporated (i.e., infused) into existing courses. Thus, it is incorporated into science, language arts, social studies, and even math. In the higher grades, it is sometimes infused, very effectively, into home economics and agriculture and, to some extent, music as well.

Using the infusion process, the *language arts* teacher, for example, could teach library skills using environmental issues as the focus for that research. Research papers could be assigned that permitted the student to select an issue of particular importance to him/her, investigate that issue using secondary sources, write the paper and, perhaps, report on the research to the entire class.

Infusion of EE into a school program is not an easy task. There are no easy answers!

The case for infusing EE into the *social studies is* outstanding. Environmental issues are, by and large, a function of human manipulation of the earth's resources. The use and abuse of space, air, water, soil, plants/animals, minerals, etc. results in situations that end up in disagreements. An example might be rezoning crop-producing land for a shopping center or a subdivision (this happens constantly). Economic and sometimes political values lie behind the "development" of agricultural land while conservationists/ environmentalists value the retention of croplands simply because we are losing them at a phenomenal rate. These divergent values meet head-on in controversy. Thus, an issue is born. Since the issue is human-centered, the social studies offer a sound rationale for the study of environmentally-related issues.

The infusion of EE into the *science* program is, by far, the most common infusion practice. The logic for infusing EE into science does have considerable merit, because the earth's resources are, in large part, directly related to science interests. Knowledge concerning mineral resources, for example, is largely a function of geology. Atmospheric phenomena are strongly allied to chemistry and meteorology. Population dynamics and a host of other critical variables are related to ecology, and so on.

Earlier in this methods book you were introduced to the goals for science education as identified by Project Synthesis. Here, too, is a strong case for infusing EE into science, because Project Synthesis calls on science teachers to focus, in part, on science-related social issues. Environmental issues are, indeed, science-related.

Mathematics can also play a role in EE. Math skills are brought to bear on numerous problem solving activities in EE. How can one manipulate population data, for example, without using math skills? Math must be applied in surveys, questionnaires, and opinionnaires, all tools for environmental investigation .

Infusing EE into a school's curriculum is not an easy task, particularly if the EE program is to have substance and continuity. The problems are numerous. What is to be taught at a particular grade level? Are the school's teachers sympathetic with the infusion strategy? Do the teachers have the skills? Can inservice education be provided? Is there a curriculum for EE available? If not, can one be prepared? How will students be evaluated, particularly with respect to terminal objectives? How can community resources be brought to bear on the program? There are certainly no easy answers to some of these questions. Even so, the writers believe that infusion is the best possible answer for EE. A rationale for an infused EE program has recently been proposed by two midwestern professors. They maintain that "The infused EE program . . .

(1) . . . will reach more students across more grade levels (if environmental education is to be truly a life long process, infusion appears to be the best possible vehicle with which to accomplish this),

(2) . . . will not require placing a new course in an already burdened curriculum,

(3) . . . better demonstrates to students the tremendous complexities involved in environmental problems and [issues], and

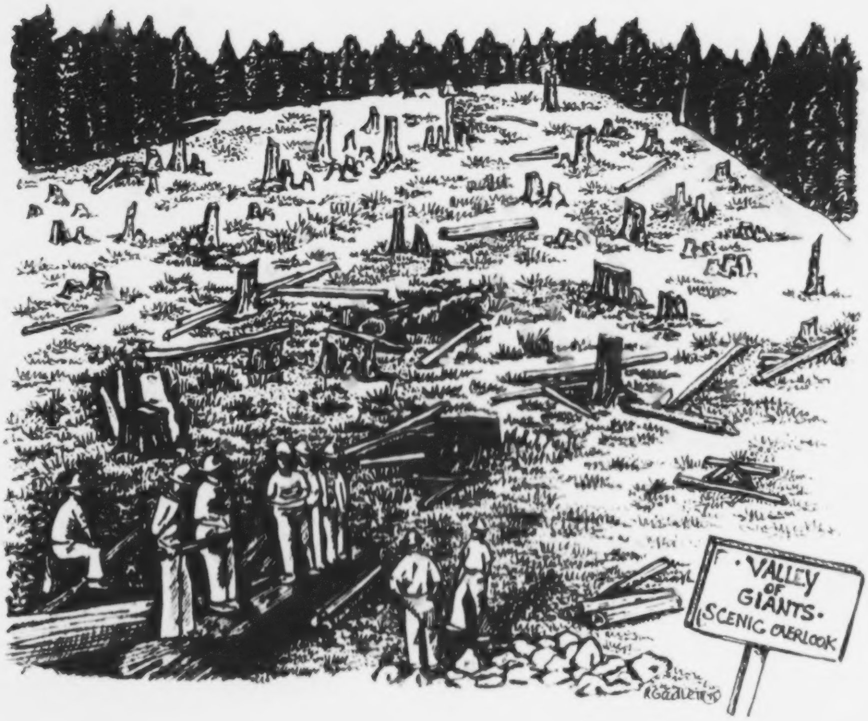
(4) . . . should result in a much greater application of environmental knowledge, skills, and attitudes on the part of individual students at the citizenship level."

Achieving Literacy! What Is Involved???

As was stated earlier, EE literacy begins with knowledge and ends with action. Seems like a simple enough idea, right? The problem is, it isn't simple at all.

Space does not permit a thorough analysis of what is known about achieving the ultimate goal of EE - the development of a citizen who is able and willing to make sound environmental decisions and act on those decisions. It may be enough to note that what is known is very complex, and what is has yet to be learned is substantial. Nonetheless, there are some principles involved of which the elementary teacher should be aware.

First of all, *knowledge* about issues - in and of itself - is not enough to promote responsible citizenship behavior with respect to solving environmental issues. The reliance on knowledge to get the job done is common in EE. Yet most research shows that an awareness of issues (i.e., simply knowing about them) is insufficient in terms of changing behavior. There is some evidence, on the other hand, that indicates that an in-depth investigation of an issue may promote changes in human values and lead to overt action with respect to that issue - at least with some individuals. However, in this instance, the investigation or information input must be thorough and fairly exhaustive.



A "belief" is something - an idea - a person holds to be true. Although it may or may not be!

Secondly, a person's perspective about an issue depends heavily upon his/her *beliefs*. A belief is nothing more than an idea that a person holds to be true. A belief may or may not be accurate (i.e., it may or may not be substantiated by reality). If the belief is erroneous, the individual's values and attitudes (andmore) can be biased in an ecologically faulty manner. The idea that, "Having three or more children poses no environmental threat" is a belief statement. It describes what an individual might perceive to be reality. In this case, the belief is faulty, according to a many ecologists. This belief does not describe a true relation between family size and ecological stability (from a population dynamics perspective). Thus, that it becomes important for the environmental educator to provide information concerning issues that is both accurate and thorough.

Third, how a person feels or behaves with respect to an issue is closely related to his/her *values*. A value, here, is defined as the relative worth someone places on something. The comment, "Large families are both beautiful and desirable" implies, perhaps, both aesthetic and social values placed on large families by the individual. Note that the *value component is different from the belief component* although, in this instance, they are compatible with each other.

Fourth, *attitudes* are also involved in this analysis of the task of achieving environmental literacy. And attitudes are difficult to define, because they are complex entities. Let us simply define attitudes as perceptions that predispose an individual to behave in certain ways. Attitudes are typically considered to have knowledge, emotional (affective), and behavioral components.

Attitudes may often be considered as perceptions that result from a personal integration of beliefs, values, and behaviors. Just how these components interact with each other is uncertain - researchers are just not sure how the variables interplay. Even so, we do know some things that are important. For example, an individual may reject new information out-of-hand if it disagrees with a strong value perspective or belief system that has been handed down by a loved or respected parent/friend. An individual who has strong anti-abortion beliefs and values will probably reject abortion as a contribution to human population control. Those who reject abortion may well turn to arguments such as sex education, birth control, or adoption of unplanned offspring as the only viable alternatives to abortion even though it appears that sex education is not always effective (and is, itself, controversial), few readily available contraceptives are foolproof and many adolescents and young adults will not turn to them for protection, and adoption still places an additional child into the population. In other words, social forces may well dictate attitudes irrespective of factual arguments that would indicate a need for alternative beliefs/values/attitudes.

The relative worth a person places on something is its "value".

Let us take this integrative process one step further. Generally, values impact upon attitudes to a greater degree than knowledge (beliefs). We already know that values are used to screen new information that may be modified or rejected as a function of those highly-prized values. If at-

The term "attitude" is sometimes defined as a perception that predisposes a person to behave in a certain way.

titudes or behaviors are to be changed in the case of a highly volatile issue, some form of dissonance must be perceived by the individual regarding irreconcilable differences between his/her beliefs and values.

In the case of population, the individual must come to *value* human population stability and its ecological implications. If such a value can be internalized, new information supporting that value will be processed and integrated into the attitude which predicts behavior. How is this accomplished? We are not certain! What is certain is that, with an issue as volatile as this one, the evolution of new attitudes may be hard to come by. The answer probably lies in a close inspection of personally-held values *combined* with accurate and fairly thorough information concerning a broad spectrum of topics (e.g., population dynamics, human population projections, immigration problems/patterns, birth control and contraceptives, cultural biases toward family size, ecological implications of eruptive populations).

The human population dilemma is a terribly complex mix of issues ranging from family size to immigration. In this photo we see a large family group in the Yucatan Peninsula of Mexico. This family lives in poverty without running water or toilet facilities. The relationships between family size, education, and poverty are strong and the associated issues are very complex and difficult to resolve. Photo courtesy H. R. Hungerford.

It goes without saying that, in order to promote responsible attitudes/behaviors, environmental educators must deal with the beliefs and values of students. This is a real problem when we realize that each learner has a unique set of beliefs and values which results in a very personal frame of reference concerning an issue or group of issues. Further, indoctrination of students is undoubtedly counterproductive. To directly confront a student's value system will probably result only in a deepening commitment to previously held values. In addition indoctrination is highly unethical.

In a democratic society, educators must strive for honesty in instruction and the development of effective problem solvers and participatory citizens. If teachers help

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students to become skilled problem solvers (e.g., investigators and evaluators of environmental issues) the students will probably sort through their own values with respect to environmental concerns and, in almost all cases, line up on the side of environmental integrity. The reader should note that these words are more than just "catch-phrases" in education; there is evidence that this prescription does, in fact, work.

Fifth, how a person behaves is related to a phenomenon called *locus of control.* Locus of control is a factor associated with an individual's perception of whether a particular behavior will result in an anticipated reinforcement for doing (acting). This is called *expectancy of reinforcement.*

Persons with an internal locus of control tend to feel as though they can exercise some control over the events in their lives. They are not content simply to be pushed around by external events.

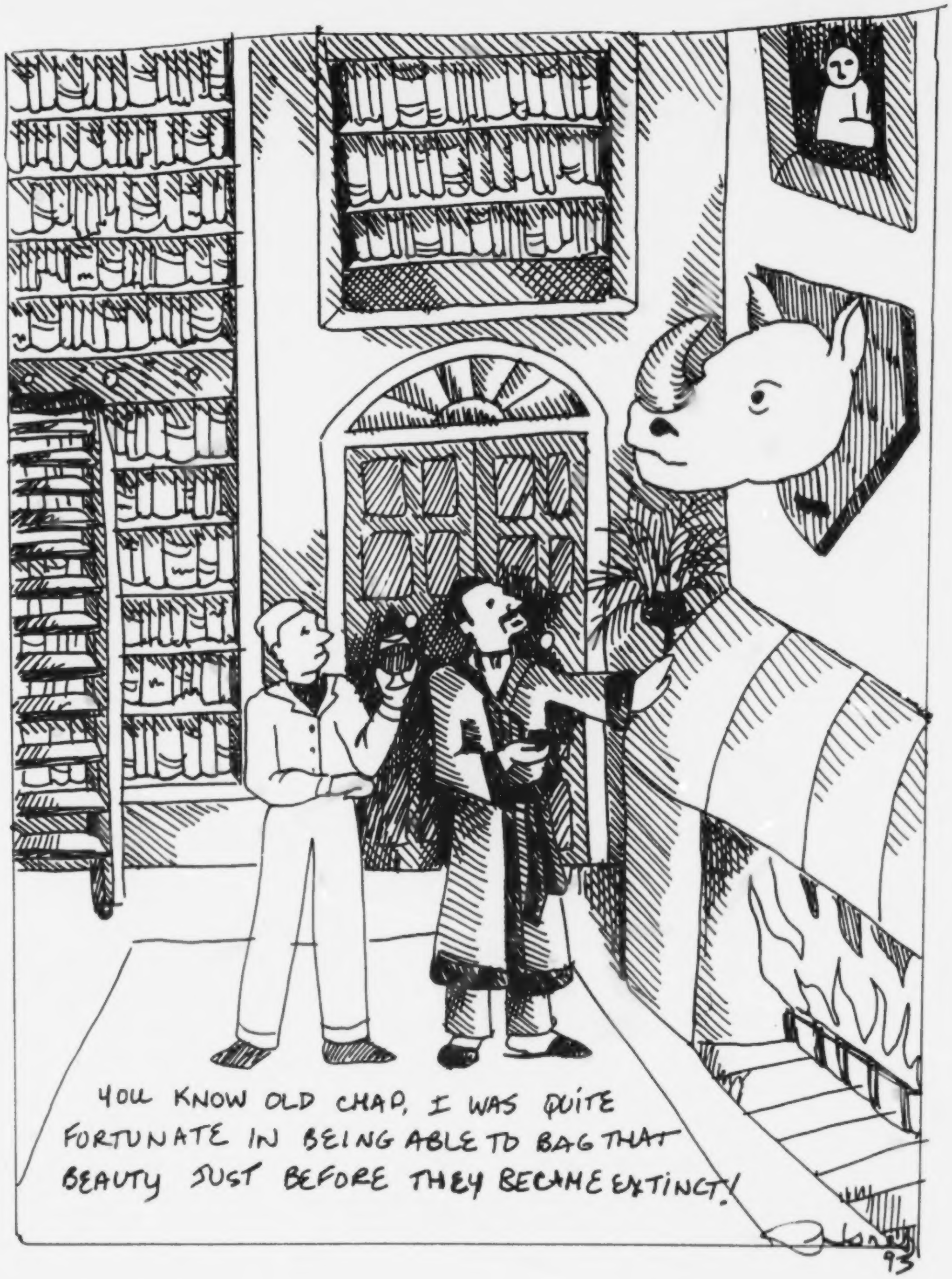
Some individuals believe that they are in control of situations that demand action. These individuals have a *high* expectancy of reinforcement. Such people are said to possess an *internal locus of control.* Internal locus individuals would tend to take action on an issue because they feel that their actions would, in some way, help alleviate the issue. On the other hand, some individuals believe that they are not in control. Therefore, they have a *low* expectancy of reinforcement. These individuals are said to have an *external locus of control.* This simply means that the control over a situation lies external to the individual—at least, the external individuals believe that. External people may, for example, believe that "powerful others" are in charge and will dictate the outcome of a problem or issue.

Going back to the population issue for a moment. let us take a look at locus of control in that context. Who, for example, would you expect to use birth control methods while engaging in coitus? Yes, you would expect birth control to be utilized widely by people who felt in control of conception. And research indicates that you are right! Internals tend to use contraception while externals tend not to.

Are internals and externals consistently one way or another? There is some evidence that indicates that people may be internal in certain situations and external in others. There is also some evidence that indicates that some individuals can, indeed, be motivated to move from an external perspective to an internal one. If this is correct, there are important implications here for EE. Although it is unclear precisely what factors are involved in such a change, it is probable that an external will move toward an internal perspective if he or she: (l) understands the issue in depth, (2) believes that action is called for, and (3) knows which action might maximize the possibility of exercising control over the outcome. If this is correct, environmental educators should focus on crucial local or regional issues (rather than the global ones so often considered), delve into issues in depth, and provide training in citizenship action skills that can be applied to those issues.

Sixth, an individual who has a high degree of sensitivity toward the natural environment is more prone to deal with the environment in ecologically appropriate ways than others. The sensitive individual (all other things being equal) is the one who . . . refuses to litter highways and natural areas . . . conserves natural resources . . . works to preserve ecologically important natural areas . . . strives for ZPG . . . respects hunting and fishing laws . . . insists on rational zoning requirements . . . etc.

What is *environmental sensitivity?* It is, by and large, an empathetic or understanding view of the environment. It is a view that respects ecological integrity, and one that believes that humans must live, somehow, in ecological harmony with the natural environment.


YOU KNOW OLD CHAP, I WAS QUITE FORTUNATE IN BEING ABLE TO BAG THAT BEAUTY JUST BEFORE THEY BECAME EXTINCT!
93

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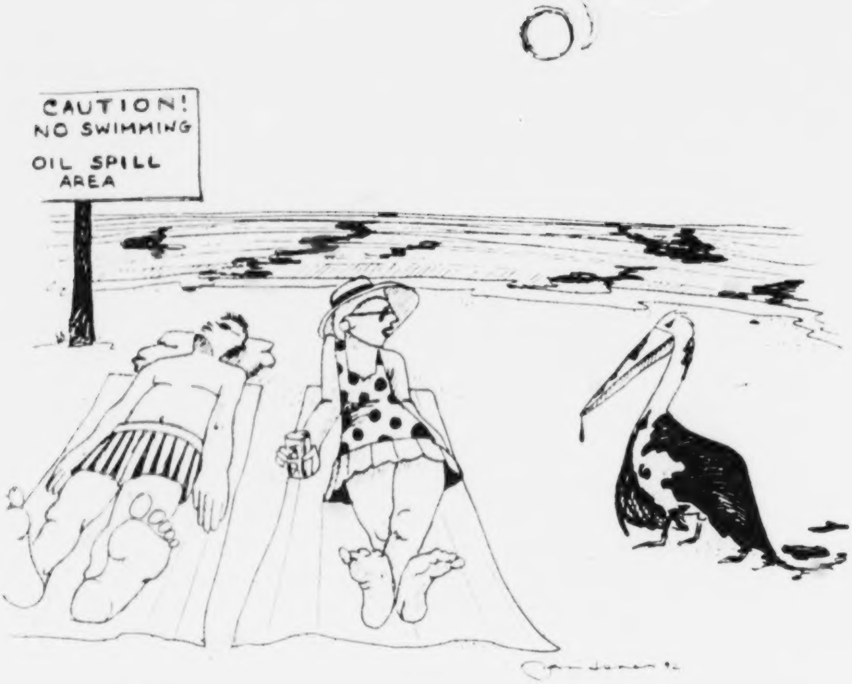


Oh Ben, do you think that pelican has an opinion on oil spills?

If sensitivity is such an important variable, why not focus on it solely and change the perspectives of every youngster in the schools of the world? Unfortunately, this is easier said than done. A high degree of sensitivity seems hard to come by. Research, again, indicates that the very sensitive individual is one who grew up closely allied with a natural setting and spent considerable time in that setting - or, experienced the loss of a highly regarded environment, e.g., a much-loved forest being cut down to make way for a shopping center. Some sensitive individuals report another variable as being crucial. That variable is associated with role models. The person(s) who acted as the role model(s) demonstrated a high degree of sensitivity that was emulated by the recipient of that experience. Role models were often members of the immediate or extended family. In a surprising number of cases, the role model was a teacher.

Environmental Sensitivity is an empathetic or understanding view of the environment. . . . that respects ecological integrity, and . . . believes that humans must live in ecological harmony with the natural environment.

Since teachers who served as role models for environmental sensitivity were sometimes reported to be precursors to sensitivity, there is some opportunity for the development of sensitivity by teachers. However, the teacher would have to fit the sensitivity model rather well, reflect it diligently, and have such a positive relationship with students as to make them eager to associate with that posture.

How many teachers are willing to express that level of dedication to their charges? Probably only a few will be so inclined. Thus, it becomes obvious that the school is situated so as to have relatively little control over the development of intense environmental sensitivity. This may, in part, be an ominous sign.

Seventh, there is some evidence to indicate that individuals who are knowledgeable about *environmental action strategies* and skilled in applying them will, in fact, use them in an effort to remediate issues. We are not certain as to the entire meld of variables associated with this phenomenon, but it appears to be an important one. If, in fact, students can be taught about citizenship actions and trained in their use more citizens would eventually confront environmental issues. Unlike sensitivity, environmental action can be taught in the classroom. This has been demonstrated numerous times by both teachers and researchers interested in EE. The teaching of environmental action in classrooms across the nation could well be the key needed to unlock the door to some semblance of environmental integrity, nationwide.

Individuals who are knowledgeable about environmental action strategies and skilled in applying them will likely use them in an effort to remediate issues.

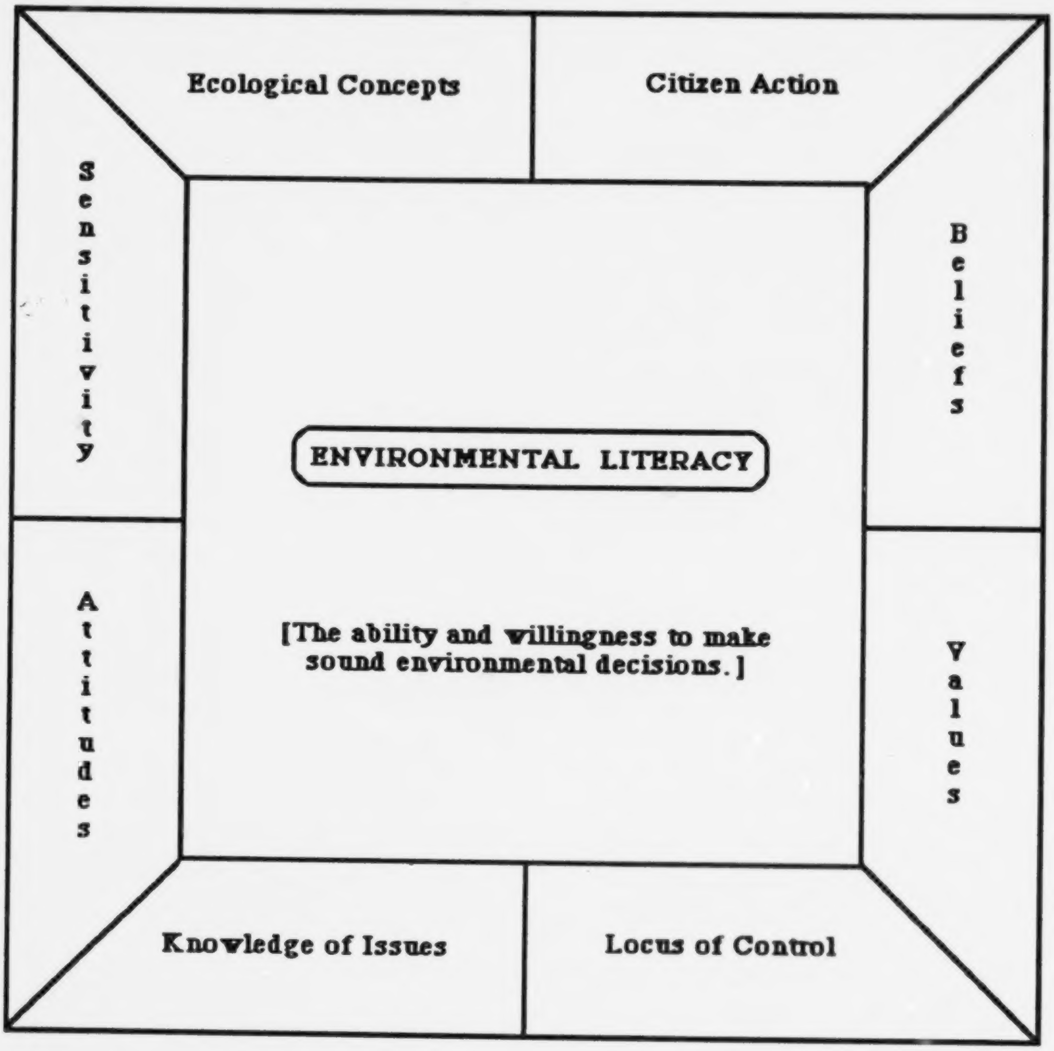
Eighth, and lastly, a knowledge of basic ecological concepts seems to be an imperative in the development of environmental literacy. Although this may seem, on the surface, to be an unimportant variable, it may be pivotal to the entire process. Why?

When an individual makes a decision concerning an issue, that decision will have ecological consequences if carried out. Thus, it seems imperative for the individual to be able to assess the ecological consequences of a given decision. You may recall that, earlier in this chapter, the major goal of EE was presented. This goal states that *environmental decisions should be made that are consistent with both a quality of life and an equally substantial quality of the environment. Environmental quality is, in large pan, dependent upon the ecological integrity of that environment.* Thus, ecological concepts become crucial to the decision-making process. A listing of several of these concepts can be found under Literacy Component I, described earlier in this chapter.

A knowledge of basic ecological concepts seems to be imperative in the development of environmental literacy.

The eight variables discussed in this section are ones which appear to be, both individually and collectively, crucial to environmental education. These are, in order of presentation: (l) knowledge of issues, (2) beliefs concerning issues, (3) the individual's value perspective, (4) a person's attitudes, (5) locus of control, (6) environmental sensitivity, (7) knowledge of and skill in environmental action strategies, and (8) ecological concepts. Exactly how these variables interact with each other is unknown. However, the crucial nature of these eight conditions must not be ignored simply because we do not know for sure how they interact. What is known is that certain of these, by themselves, will *not* result in a literate citizen. Attention should be given to all eight with an emphasis placed on beliefs, values, and action.

IMPORTANT VARIABLES ASSOCIATED WITH LITERACY


Ecological Concepts
Citizen Action
Sensitivity
Beliefs
ENVIRONMENTAL LITERACY
[The ability and willingness to make sound environmental decisions.]
Attitudes
Values
Knowledge of Issues
Locus of Control

This figure illustrates the important variables associated with environmental literacy. Note how each of these is shown to interact with all others. Although research has not revealed the exact nature of these interactions, they most certainly do occur.

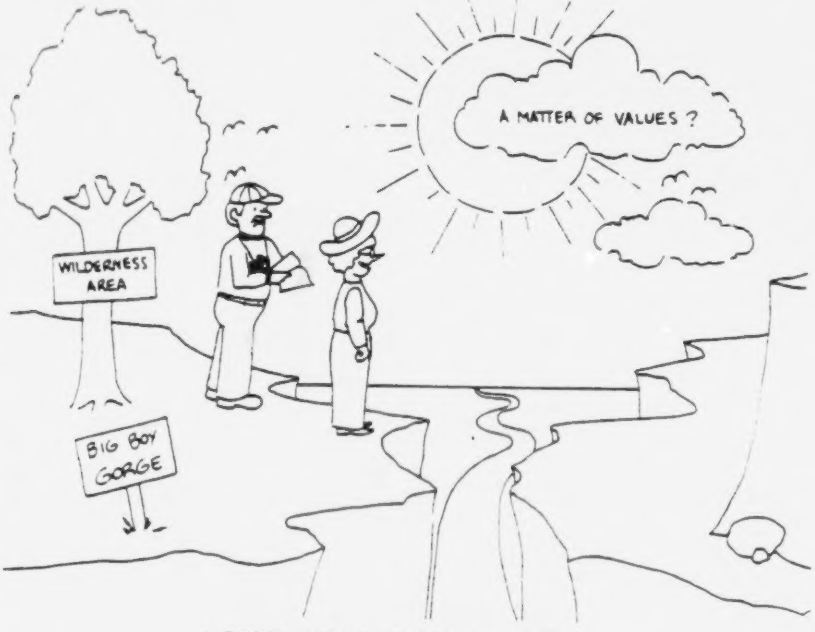
The research is very clear on the matter. Citizenship behavior can be developed through environmental education. The strategies are known. The tools are available. The challenge lies in a willingness to do things differently than we have in the past.
H. R. Hungerford & T. L. Volk, 1990

More on Values - The Role of Values Analysis

Environmental literacy is very dependent on the individual continually evaluating personally held values. This evaluation should go on continuously, prompted by new information or new experiences with the environment. Teachers can stimulate a more rapid evolution of personally held values by providing information and experiences designed to do exactly that. This might infer that the professionals doing the stimulating hold the "correct values". Although some teachers might believe that they have "the answers" it is totally unethical to attempt to superimpose personally held values on the students.

In the traditional sense, values cannot be taught. When people go through the process of values clarification they do so in a very private and personal manner. No amount of preaching or intimidation will make a person truly accept a value position. Of course, students might verbalize a particular value, or behave as if they had that value in order to avoid ridicule or punishment. But, this mode of behavior is artificial and will be reversed as soon as the threat is removed. The values that count are those that human beings accept and act on freely and consistently. Therefore, it is crucial that the teacher attempt to promote an educational climate in which values can be chosen freely from available alternatives, tested against logic, and acted on. We call this educational climate a "value fair" setting (i.e., a setting in which values can be analyzed, communicated, and tested without fear of ridicule).

Look to the following page for an activity that should work well for values analysis. The educational worth of this activity will be determined, in part, by the teacher's ability to ask questions that give the students an opportunity to analyze their own values and those reflected in the story. Excellent class discussions can result from such an anecdote and the teacher must be cautious in deciding to what extent to permit the discussion to "heat up" if there are sharp differences of opinion (differing values) across the class.



I DUNNO HAROLD, THERE OUGHT TO BE ROOM FOR JUST ONE McDONALD'S!

A Problem for the Johnsons

In 1988, Mr. and Mrs. W. R. Johnson purchased a home on the outskirts of Bigsville for $59,850. Over the next few years, land and building values increased so that the Johnsons felt perfectly comfortable when they finished the basement and added a garage and a workroom for Mr. Johnson. In 1972, the Bigsville Airport Authority condemned nearly 1000 acres of land just a mile or so north of the Johnson home. In 1976, an international airport was in service where there had been only farm land before. The Johnsons found that the north-south runway was due north of their home. The noise was awful.

Since the development of the airport, highway construction and traffic has increased over 100 times. Noise levels are, in the entire area, a serious environmental problem. Crime has increased over 250%, and property values have decreased greatly. Today, the Johnson residence is barely worth $48,000, even with the additional money invested and inflation. In another area, their home would be worth up to $80,000.

The biggest problems for the Johnsons are economic and psychological. The Johnsons did not anticipate living near a jetport, nor did they anticipate an increase in crime and noise levels. Certainly, they did not anticipate a tremendous decrease in property values.

Possible Questions.

1. What were the values that might have been held by the Bigsville political leaders who chose to construct the airport in the first place? Do you think that their values were the same as the people living around the area taken over by the airport? Why?

2. What options are available for the Johnsons? What positions do you think the Johnsons should take with authorities in this situation? Why?

3. What responsibilities, if any, does the Bigsville Airport Authority have in this situation? Why do you think so?

4. Assume that the entire area was equally disturbed by the airport. Would an environmental action citizens' committee be able to help? How would such a group go about getting something done? What if the committee finds out that the only hope is to conduct itself in an illegal manner? Should they continue their efforts? Why? Why not? What values would be reflected in the decision?

5. Is there a "way out" of this situation for the Johnsons? If so, what alternatives do you think they might have? Which of these alternatives might prove most effective?

Now, what about some of your own environmental beliefs and values? The following activity has been designed to demonstrate the divergence of beliefs and values that can exist in both preservice and inservice teacher populations. It has been used many times with success. Please complete this brief activity, following directions carefully.

Let's Compare Beliefs and Values

This activity is designed to let you compare a few of your environmental beliefs and values with those of your peers. On the next page you will find a list of eight statements with which you may agree or disagree. Following each is a number line ranging from "strongly disagree" to "strongly agree." You are asked to circle the number of the response which *best* reflects how you feel about the statement. Please do this before going on to the rest of the activity.

1. The killing of deer by hunters is an important part in keeping deer herds healthy.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

2. The great whales don't belong to any nation and, therefore, any nation that wants to hunt them should have the right to do so.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

3. Human females should not have more than two children.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

4. Although landowners hold title to farm land, there should be regulations that guarantee that farm land will not be converted to non-agricultural purposes.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

5. The recycling of metals such as aluminum and steel should be mandatory, even if it is not always profitable.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

6. Air pollution standards should be relaxed in order to get better gas mileage in automobiles.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

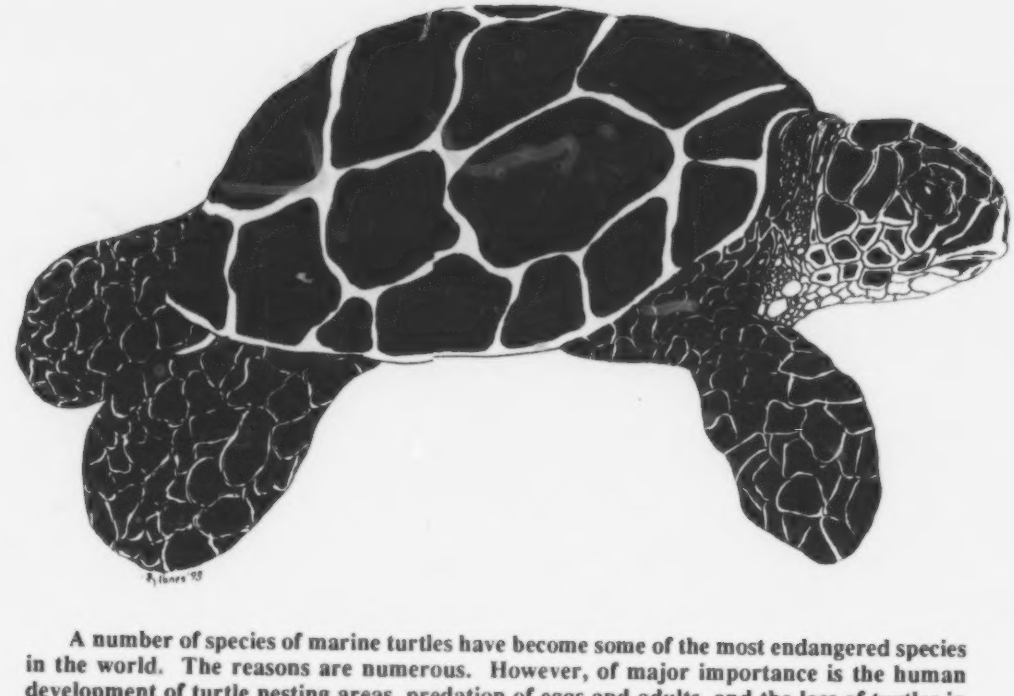
7. Only those people who live alone or have special problems should be allowed to keep a dog or a cat because of the tremendous amount of food energy consumed by pets.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

8. Nuclear power plants should continue to be built in order to produce needed electrical energy .

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

On the next page you will find a summary chart. After everyone in class has responded to the items on the previous page, add up the class responses in each category for that statement. This will clearly show whether there is a wide variation of beliefs and values within the class on a given statement. If this proves to be the case, a discussion might determine the reasons for this observation.



A number of species of marine turtles have become some of the most endangered species in the world. The reasons are numerous. However, of major importance is the human development of turtle nesting areas, predation of eggs and adults, and the loss of turtles in the nets of commercial fishermen.

Summary Totals

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

Postsummary Discussion Questions:

1. Analyze those statements for which there are wide differences of opinion. Why do these differences exist? What are the logic bases for these positions? Are these positions ecologically sound? Why? Why not?
2. Sometimes a group will tend to load on the "neutral" category. When this occurs, what might be the reason? Could this circumstance be changed through education? If so, how?
3. Why is it difficult to resolve an environmental issue where there are strong and differing belief and value positions?

A Look at Conflicting Beliefs and Values

As noted earlier in this chapter, attitudes and behavior are very complicated entities that often emerge from an integration of an individual's belief and value systems. And, of course, it is quite appropriate to think that beliefs and values modify each other to a considerable extent. As you might expect, this interplay can do some strange things to a person's attitudes and behaviors. One of the most interesting phenomena revolves around inconsistencies in the belief-value perspectives of an individual. These inconsistencies often result in certain attitudes and behaviors in some situations and others in other situations.

For example, a duck hunter may *believe* that canvasback ducks are a threatened, but desirable, species of waterfowl and shoot only one per day as the law allows. Conversely, this same hunter may shoot an extra mallard or two - over the legal limit - because they are not threatened and, in fact, quite common in the region. Thus, the hunter bases his shooting behavior and his waterfowl values on whether *he believes* a species is threatened or not. In this case, the important variable is not the law at all, but differing beliefs concerning the two species of waterfowl. What might be critical to this situation is a lack of knowledge concerning the very rigorous way in which wildlife biologists go about deciding how much hunting pressure a species can endure and still retain a viable breeding population from year to year. Given this information, the hunter *might* take on a new belief system and a different set of values resulting in a new attitude and a different (legal) behavior concerning mallards.

Let us inspect our own beliefs/values in a setting far removed from duck hunting to see if they are consistent throughout. The issue is again related to the human population.

ARE MY POPULATION BELIEFS AND VALUES CONSISTENT?

An Analysis Activity

PART I

Directions: Rank order the following population control measures with respect to your own beliefs and values concerning appropriate ways to alleviate the population problem. The one you rank No. I would be the measure you value the most. Complete this part before proceeding to Part II.

A. ____ distribute birth control information widely, beginning with citizens of approximately high school age.

B. ____ toughen up the moral fiber of all segments of society via the home, the church, etc., to reduce casual sexual behavior.

C. ____ legalize abortion for all females everywhere.

D. ____ trust the common sense of individuals to limit family size

E. ____ limit each family to two children and enforce that limitation - via sterilization, if necessary.

Now, having completed Part I of this activity, complete Part II.

PART II

Directions: Rank order the following population descriptions according to how you would value those situations. The situation you value the most would be Number 1, and so on.

A. ____ a planet without any population restrictions whatsoever.

B. ____ a planet with a replacement level (natality) equal to the rate of loss (mortality).

C. ____ a planet with a replacement level (natality) less than the rate of loss (mortality).

D. ____ a planet that is slowly, but surely, working toward zero population growth.

E. ____ a planet with a human population no more than 1.5 times the present population.

Questions:

1. Which positions in Parts I and II, if any, are consistent with each other?
2. If you ranked D in Part I highly, would **this be consistent with** B or C in Part II? Probably not! Why? Your best bet might be to rank E in Part I highly if you valued B or C in Part II. Again, why?
3. Are there any other items in Parts I and II where inconsistencies might be observed? If so, where might these occur? **Oftentimes, people are inconsistent in** their thinking. What are some of the reasons for this phenomenon related to the population problem? What might be done to correct the problems?

Having Learners Investigate Issues: A Crucial Literacy Component

You will recall that one of the four Environmental Literacy Components outlined earlier dealt with the investigation and evaluation of environmental issues. Although this literacy component is seldom successfully achieved in today's schools, it is probably critical to literacy as defined here. Why?

The successful and in-depth investigation of issues by students provides them with a holistic view of issues which cannot be duplicated by other means. When the student gathers and analyzes information, he or she assumes an ownership of that information which is impossible to accomplish via a lecture or textbook approach. Further, information collected by the student from a variety of sources tends to transcend the biases of single information sources. Thus, the student can compare information sources and separate the "wheat from the chaff," drawing realistic conclusions and making judgments about issues which are probably accurate and ones that can be defended.

When a student gathers and analyzes information, he or she assumes an ownership of that information which is impossible to accomplish with a lecture or textbook approach.

Some of the authors of this worktext have been engaged in issue investigation research for a number of years. This research has clearly demonstrates that middle school youngsters who have been trained in investigation skills can perform magnificently in issue investigation. Further, these students often attain a level of expertise on issues which is far superior to the teacher's own level of information. In fact, the authors and the teachers of these students have often learned a great deal about issues by interacting with those who have completed in-depth investigations.

A question may arise concerning the issues which are to be investigated. If one assumes that some issue awareness has preceded the investigation stage and that the teacher has carefully focused on crucial environmental issues (e.g., population, land use management, energy, threatened and endangered species, toxic waste disposal, etc.), one has little to fear with regard to the issues the students will choose to investigate on their own. The bottom line is simply to permit the students to select the issues they will investigate after becoming aware of issues and being trained in investigation skills.

Students will not always select the most pressing issues to investigate. This is perfectly all right in that every student should not be expected to be interested in the most crucial issues (for investigation purposes). Over the years, a wide array of topics have been chosen by middle and secondary school students . A few of these topics are:

Wild Horse Management in Nevada
Nuclear Power Generation
The Killing of Fur Seals
Abandoned Automobiles
Reintroduction of Timber Wolves
Recycling Habits of Community
Water Loss in School From Leaky Faucets
The Great Whales
The Alaskan Pipeline
Detergent Use/Selection
Water Pollution
Solid Waste Management
Regional Perspectives on Acid Rain
White-tailed Deer Management
The Tuna/Porpoise Controversy
Lead vs. Steel Shot (Duck Hunting)
Wilderness Preservation
Whooping Cranes
The California Condor
Land-Use Management
Reclamation/Surface Mining
Zoning Issues
Waste Oil Disposal
Disposable Diapers
Christmas Tree Recycling
Community Composting
The Delmarva Fox Squirrel (Maryland)
Tiger Shark Management (Hawaii)

The list above represents a broad spectrum of issues or **issue-related topics.** One might question this particular selection of issues, but it should be remembered that *these* were the *issues chosen by the students* - ones they wished to investigate. In addition, research has shown that animals are of extreme interest up to and including adolescents and this may account for the numerous topics dealing with endangered species.

More importantly, perhaps, are the skills associated with the issue investigation. In learning how to investigate issues, students acquire a set of skills which are very sophisticated and can be broadly applied in a variety of settings - even beyond the confines of the environmental. These skills are reflected in the objectives set forth in a set of modules designed to provide investigation skill training. A few of the more important objectives are found listed below. You may be surprised when you read this list of objectives and realize that children as young as fifth graders regularly receive this training.

Sample Objectives

1.... compare two different information sources and communicate how they differ.
2.... identify governmental or private agencies that can be written to for specific information.
3.... write letters requesting specific information.
4.... identify value positions expressed in environmental news articles.
5.... summarize environmental news articles (or other information sources).
6.... locate information references in the card catalog.
7.... locate information sources in the Readers' Guide.
8.... communicate the rules that tend to govern the use of surveys, questionnaires, and opinionnaires.
9.... identify issues that can be investigated using surveys, questionnaires, and opinionnaires.
10.... design surveys, questionnaires, or opinionnaires as needed.
11.... identify conclusions which are appropriate for research data.
12.... write inferences which are logical and based on observations.
13.... write recommendations which are appropriate for particular research findings.
14.... evaluate conclusions, inferences, and recommendations written by others.
15.... contract with the instructor for the completion of an issue investigation - an issue selected by the student and approved by the instructor.

Subsequent to the completion of issue investigation, it is an excellent idea for the teacher to set aside time whereby the students can report on their investigations, display the data collected and share their conclusions and recommendations with the entire class. Interestingly, there have been times when these investigations have been shared with school administrators, the police, city councils. etc., in an effort to sway authoritative opinion in a manner deemed appropriate by the students. Even more interesting is the fact that the students have at times, been successful in getting something done (e.g., water conservation practices enacted, abandoned vehicles removed, etc.)

Under no circumstances, however, do the authors believe that students should be forced to undertake actions such as these. The decision to take action must be the students' and no one else's. The reason for this is simply a matter of professional ethics. Once environmental action is engaged outside the classroom, the students are conducting themselves as participatory citizens, acting on their own belief and value systems. Thus, the authors believe that the teacher must not superimpose his/her beliefs and values on the student when they are behaving as participatory citizens in the community.

Educating for Citizenship Action

The decision to take action must be the student's and no one else's.

Regardless of how the teacher goes about environmental education, the eventual outcome should be a skilled and informed citizen who is both willing and able to take action in the solution of environmental issues. Unfortunately, there are few programs that actually attempt to develop environmental action skills in students. The reason for this state-of affairs is not clear, but it is probably due to the fact that most EE programs go about the business of making the student environmentally aware, with the assumption that this will lead to action. This assumption is incorrect! Students should be given direct instruction in environmental action strategies if this is a desired outcome of EE.

Teaching for environmental action should include, among other things, information on the wide array of possibilities that exist for positive action. These possibilities range from *individual citizenship action* to group *action*. Further the power of group action should be stressed in that coalitions of human beings can usually exert more influence than can the individual, working alone. Similarly, group action can vary from that expressed by a student council or a neighborhood coalition to that expressed by international organizations like the Nature Conservancy, the World Wildlife Fund, or Ducks Unlimited. Also of great importance are the categories of action and the skills inherent in these categories. These include *persuasion, political action, legal action, consumerism, ecomanagement* (physical intervention), or *a combination of these.* Interestingly, every elementary school youngster can get involved in all of these with the exception perhaps of legal action. A definition of each of these follows:

A group of human beings working together can usually exert more influence than can an individual, working alone.

Categories of Citizenship Action

Persuasion. ... an effort to verbally motivate human beings to take positive environmental action as a function of modified beliefs and values.

Political Action. ... an effort aimed at persuading an electorate, a legislator/ legislature, or executive governmental agency to conform to the beliefs and values held by the person(s) making the effort.

Legal Action: . . . any legal or judiciary action taken by an individual or group or organization aimed at some aspect of environmental law enforcement or a legal restraint preceding some environmental behavior perceived as undesirable.

Consumerism. ... an economic threat by an individual or group aimed at some form of behavioral modification in business or industry.

Ecomanagement. ... any physical action taken by an individual or group aimed at directly maintaining/improving the existing ecosystem.

In addition, emphasis should be given to the important constraints that must be placed on action. These constraints implythat there are some serious questions that must be attended to before an action is taken. The writers of this worktext, working with other curriculum developers in EE, have identified a number of questions that should be answered before an action is decided on. They follow:

Action Analysis Criteria

1. Is there *sufficient evidence* to warrant action on this issue?
2. Are there *alternative actions* available for use? What are they?
3. Is the action chosen the *most effective* one available?
4. Are there *legal consequences* of this action? If so, what are they?
5. Will there be *social consequences* of this action? If so, what are they?
6. Will there be *economic consequences?* If so, what are they?
7. Do my (our) *personal values* support this action?
8. Do I understand the *beliefs and values of others* who are involved in this issue?
9. Do I (we) understand the procedures necessary to take this action?
10. Do I (we) have the *skills* needed to take this action?
11. Do I (we) have the *courage* to take this action?
12. Do I (we) have the *time* needed to complete this action?
13. Do I (we) have all of the *other resources* needed (other than the above) available to make this action effective?
14. What are the *ecological implications* of this action?

Action Case Studies

Action Categories	The Case Study
Persuasion and Political Action	Middle school students in southern Illinois became involved in plans to dam a particularly scenic and scientifically rich canyon. Students wrote to government officials at the state and national levels. They prepared editorials for the local newspapers. The canyon was not dammed and they felt that they had a part in the decision making process.
Ecomanagement	Middle and senior high students in a midwestern community became concerned about the eastern bluebird as an endangered species. They constructed more than forty nest boxes in an effort to improve bluebird population levels in the area. All nest boxes were installed on rural university property. Follow-up observations indicated that the project was a success.
Persuasion	Middle school students in another midwestern school became distraught over the amount of water being lost due to leaky faucets in their school. They took careful measurements and determined that the annual loss cost taxpayers in excess of $100. The students put up a poster communicating their findings (without the knowledge of the teacher) and the faucets were repaired within a twenty-four hour period.
Ecomanagement and Persuasion	Students in an eastern urban area became concerned about the environment around their middle school. They gained permission to landscape the grounds, plant gardens in bare areas, and beautify the area generally. A school-wide campaign was conducted to get students to help protect seed beds and saplings. Community support grows for the project.
Ecomanagement and Persuasion	Art students in a Missouri elementary school decided that the exterior of their school was being defaced at an alarming rate. With the cooperation of their art teacher, they got permission to paint murals on the metal panels being defaced and worked to get other students interested in the aesthetic potential of the school site.

The person who cares effectively is one who is willing to pattern his or her action in accordance with those rules of conduct most likely to meet the requirements of an ideally nurturing environment.

Robert C. Fuller, 1992

An Analysis of Sample EE Strategies

On the following pages you will find two sample strategies that have been widely used in EE. These activities are incorporated here for two reasons. First, you may want to adopt them for use in your own classroom. Second, you are asked to critically analyze these strategies to determine the extent to which each of these incorporates problem-solving skills, values clarification, math, science, language arts, and/or social studies.

Resource Worksheets

A natural place to begin dealing with environmental problems is in the students' own community. Many teachers prefer to have students gather data and come up with their own generalizations concerning specific, local environmental problems or management practices. One technique that successfully involves the student in such investigation is called the **"Resource Worksheet."**

Students are given data collection worksheets covering one of a number of different environmental topics (e.g., the business district of the community, the city water works, the sewage plant, the local landfill, or local strip mines). Students collect data individually or in small groups and bring this information back to the class. Numerous extension activities can grow out of this strategy, including action projects aimed at improving resource management at the local level. One such worksheet is entitled "The City Water Works." It follows:

Worksheet: The City Water Works

1. Briefly describe the geographic location of the city water works.
2. What is the source of raw water for the community, and where is this source located?
3. Are there alternative sources of water? What are they, and where are they located?
4. Make a simple diagram of the flow of water from its source to the final storage tanks. Include each step in the treatment process.
5. Are there any special treatments needed before the raw water is fit for human consumption? If so, what are they? How often are they monitored for health and safety? How are they monitored?
6. Are the facilities large enough to maintain an adequate supply of water 24 hours a day? What is the evidence for this?
7. In the case of fire or other emergency, is there an adequate reserve of water?
8. Does the water treatment plant have sufficient capacity to meet growing demands for water next year? . . . next two years? . . . next five years? . . . next ten years?
9. Can the source of the raw water supply enough water for the growing demands over these same time spans?
10. What training is provided for the city water works operators?
11. Home owners are charged for the water they use. Is the city using the most economical method for providing water to home owners? What other methods might be available?
12. What problems, if any, do the water works employees identify as being related to local water consumption, supplies, pollution, etc.?
13. Do you have any suggestions as to how you or your class might help solve any existing water resource problems? Might it be possible to sponsor a community water use awareness campaign in order to get home owners to reduce water consumption?

Worksheet: Determining Water Consumption

The analysis of a person's own water consumption is an excellent follow-up activity to the one described above. This strategy could also be used without the prerequisite of investigating the local water works. In any event, this particular investigation has been used successfully in the middle years. It is a proven values analysis activity, and can result in better water management practices in the home.

Determining Water Consumption

How much water do you use? How much water does your family use? How does this compare with other homes in the community? Is this water consumption necessary? How much water could be conserved throughout your community if every home owner and renter chose to use the minimum amount needed for good health and cleanliness? How much could be conserved nationally? These are a few of the questions you can attempt to answer through this activity.

The first task is to determine the weekly consumption of water in your own home. Below, you will see a list of uses of water. By carefully observing and measuring water consumption in your own home, complete this computation. (You may need to figure out some interesting ways to make some of these measurements!) Be sure to include all uses you can think of besides those listed here.

Home Water Consumption

Use	Gallons Needed Per Week
Drinking and food preparation	____________
Dish washing	____________
Clothes washing	____________
Car washing	____________
Bathing, showering, general washing	____________
Toilet flushing	____________
Garbage disposal (if mechanical)	____________
Watering grass, gardens, etc.	____________
Water for pets—drinking, bathing, etc.	____________
Water lost from leaking faucets	____________
OTHER ____________	____________

Total gallons used per week = ____________

Divide the "Total gallons used per week" by the total number of persons in your home. This will give you the average number of gallons used per person per week. Gallons per person per week = ____________

The second task is to determine the minimum **amount of water needed** for all uses in your home. It is sometimes amazing to discover that considerable water can be saved by changing a few personal habits, repairing leaking faucets, etc. How much is really needed? Compute the minimum needs below:

Minimum Home Water Needs

Drinking and food preparation ____________
Dish washing ____________
Clothes washing ____________
Car washing ____________
Bathing, showering, general washing ____________
Toilet flushing ____________
Garbage disposal (if mechanical) ____________
Watering grass, gardens, etc. ____________
Water for pets—drinking, bathing, etc. ____________
Water lost from leaking faucets ____________
OTHER ____________ ____________

Minimum gallons needed per week = ____________

Again. divide this sum by the by the total number of persons in your home to get an average. Minimum number of gallons per person per week = ____________

At this time subtract the minimum number of gallons per week from the original number of gallons per person per week. This will give you the amount of water that can be conserved per person per week. ____________

How many gallons can you save per person per week? ____________**gallons**

How does this figure compare with the water savings computed by other students in your class?

What seems to be a reasonable number of gallons that could be conserved by all people you know? This will be determined by discussing average water uses in homes in your immediate area (for example, other members of your class).

How much water could probably be saved per person per week in your community? ____________**gallons**

At this point you are to find out the population of your community. Multiply the newest average number of *gallons saved* by the population of your community. This will give you an estimate of the amount of water that could be conserved in your community alone .

Estimate the amount of water that community. _____________gallons

Next, compute the number of gallons that could be conserved in the community each year. Simply multiply your last figure by 52.

Estimate the amount of water that could be conserved each year in your community. _____________gallons

Would this estimate of the water that could potentially be saved have an impact on water resources in your area or community? Would it conserve the underground water supply? Might it help solve a dangerous water shortage? Would it mean less stress being placed on the municipal water works? On the sewage disposal system? You might call the water company and the sewage disposal facility and inquire about these last two questions .

How would your estimate of water consumption savings in the home look on a national basis? It is a relatively simple matter to compute this. Simply find out the present population of the U.S. and multiply that number by the gallons saved per person per week. However, remember, if there is an error in your original estimate, you will be multiplying that error by that number!!!

APPENDICES

APPENDIX A

A Short History of Elementary Science Methods in the United States

In the Beginning—The Didactic Era

The beginning of science education for children in the United States can be traced as far back as the late 1700s. Children's books, called the children's literature or the didactic literature, were the first method of elementary science education. These books were originally of British origin. Many of them were brought to the United States and were adapted to the new world and reprinted by American publishers.

The early American versions of the didactic literature had several purposes. One such purpose was to develop ethics, morals, and manners in youngsters. Within the stories, children were shown the value of neatness, unselfishness, amiability, honesty, carefulness, etc. Another purpose of the children's literature was to stimulate the child to develop, on his own, some of the critical thinking skills such as observation, comparison, and experimentation. Transmitting scientific information, concepts, and principles from the written page to the child's head was yet another purpose of the didactic literature. Such topics as animals, plants, the solar system, seasons, and refraction of light were among those covered in the children's books.

Religious Influence On Early Science Education

During the time that the didactic literature was being printed in the United States, religion was a dominating influence on people's lives. This domination was reflected in the children's literature. Children were taught a reverence for natural history (i.e., the objects and events of nature). It was believed that by developing a reverence for nature the youngsters would develop a reverence for God at the same time, since God was the creator of the universe including all of the natural world.

Additional religious influence of this era on the children's literature can be seen in terms of anthropomorphic and teleological references. The practice of tendering human characteristics to other life forms—anthropomorphism—was a common one. Thus references like the sly fox, the busy bee and the wise old owl crept into children's reading matter. Anthropomorphic references were to serve as models, after which children could pattern the building of their own characters. Another common practice of the era was to explain a phenomenon teleologically. That is, naturally occurring objects and events were explained in such a manner as to make the reader perceive that they were predestined to be that way. A tree, for example, grows where it does to provide shade for children. The cow is here to give milk for people to drink. A storm is God's will.

Even in present day literature, one can still find anthropomorphic and teleological references made to the objects and events of nature. However, the professional opinion today is to eliminate both from science literature because they tend to promote inaccurate and even debilitating conceptual perceptions of the universe.

The didactic literature, at its inception, was designed to be used by private tutors or parents who taught children at home. Financially, the children's literature was within the reach of only the upper classes. As time proceeded and the books were adapted for use in school classrooms, much of the scientific content was kept, but unfortunately development of the scientific skills such as observation and experimentation were emphasized less and less. The adapted books, as school materials, had become readers, the purpose of which was to transmit information, not critical thinking skills to the students.

Object Teaching

About the same time that the didactic literature was being adapted for classroom use (1860), the "object teaching" movement was beginning to sweep through Europe and the United States. This movement was started by Pestalozzi, a Swiss of Italian parentage. A classic description of Pestalozzian object teaching is given by Krusi (1875) when he states:

> To place objects before them (children) in which they are interested, and which tend to cultivate their perceptive faculties; and at the same time, lead them to name the object, to describe its parts, and to state the relation of these parts. Thus language is also cultivated; and, from the observation of a single object, the pupil is led to compare it with others, and the first steps in classification are taken.

In the United States the best known adaptation of Pestalozzian object teaching was developed at Oswego, New York. The newly formed National Education Association supported the Oswego object teaching and so it received nearly total acceptance across the country. Object teaching was based on a child's limitations rather than his capabilities. It was thought that elementary school children could think only in terms of the concrete, not the abstract. Further, it was believed that children could not interpret events or phenomena.

For its content, object teaching turned to the objects of natural history—rocks, minerals, plants, and animals. Objects, once placed before the children, were closely and continuously observed. Likenesses and differences were noted, described, and memorized. This was, therefore, an era in which description was the key element rather than interpretation or investigation into the cause and effect relationships of the universe.

Faculty Psychology—The Basis of Object Teaching

Object teaching was based on and supported by the principles of faculty psychology. As Smith (1967) points out, "The emphasis on observation and memorization for very young children was based on the sequential development of capacities. It was falsely assumed that young children were able only to observe and identify objects but were unable to reason or to interpret phenomena." Furthermore, faculty psychology put forth the notion that the mind was a muscle that could be strengthened by exercise. Therefore, during the object teaching era, school children observed, compared, memorized, and described over and over again in an attempt to strengthen their brains.

As a method of teaching science, many contemporary writers came down hard on object teaching and its faculty psychology basis. Certainly, the psychological premise for object teaching was faulty. We know, for example, that children can intellectually manipulate basic principles of science and can interpret happenings and see relationships. Further, to focus solely on the strategies of object teaching is absurd from a general education point of view. Still, research indicates that the strategies of object teaching (critical observation, comparison, and communication) can help develop perceptual ability and, further, that these skills are retained over long periods of time and that these same skills can be transferred to new and unique situations. Thus the strategies of object teaching cannot be totally rejected for they may have some payoff value in terms of development and use of certain critical thinking skills.

Science Curriculum Failures

In the late 1800s, America was in the midst of industrial expansion. Citizens were viewing first-hand the practicability of new scientific information and its technological applications (e.g., railroads, agricultural machinery, the telegraph). As a result of science and technology's practical implications, citizens were demanding that the content of elementary school science be broadened and organized. The great interest that had been given to object teaching in the 1860s had begun to wane, and with taxpayers calling for a new curriculum, object teaching began to fall by the wayside.

For about the next thirty years (1870-1900) prominent educators spent their time attempting to develop science programs. These programs tried to expand and organize science content. Further, these new science programs included the development of critical thinking and problem-solving skills. However, due primarily to the inability of teachers to handle these new science programs, they failed to become implemented.

The Nature Study Movement

While the above mentioned elementary science programs were failing, a new elementary science thrust, the Nature Study movement emerged in response to an industrial America. As large cities grew around booming industries, young rural adults were attracted by the employment, entertainment, and excitement the cities offered. A tremendous migration toward the cities took place with the attendant problems of city crowding and unemployment.

Nature Study enthusiasts felt that if young children could be imbued with a deep appreciation of natural history they would not leave the farm for the city. Further, the Nature Study movement was aimed at improving agricultural practices, thereby stimulating the rural economy. Centered at Cornell University and headed by Liberty Hyde Bailey, the Nature Study movement provided teachers with the materials they needed to successfully teach about nature (i.e., Nature Study manuals, supplementary readings, and study guides).

The content of the Nature Study science program was, like that of object teaching, the things of nature. The material was, however, better organized and more accurate. Although the Nature Study's content was sounder than that of the object teaching era, the method of instruction was still that of object teaching based on faculty psychology. Observation, comparison, memorization, and description were once again performed over and over by students. Also, as before, the children were viewed in terms of their limitations rather than in terms of their capabilities.

Nature Study's aesthetic goal was to get children to love, respect, and protect nature. To achieve this goal, the Nature Study movement became interdisciplinary. Poetry, singing, painting, and writing were incorporated into lessons. Whether the Nature Study movement was successful or not in saturating children with knowledge about and respect for nature, the movement began to decline by the 1920s.

New Faces And New Ideas

During the second and third decades of the 1900s, men of stature set forth ideas that have affected elementary science education to this very day. Dewey's ideas about elementary science education were representative of his "learning by doing" philosophy. Dewey (1916) believed that scientific knowledge separated from the scientific processes which generated that knowledge became, ". . . a body of inert information" when presented to students. Further, he pointed out that the methodology of science (science processes) was of as great, if not greater, importance to the education of children than the knowledge of science.

In 1927 Gerald Craig (from Columbia University) published his dissertation *Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School.* Craig's dissertation served as a focal point for change in the American elementary school, and many of these changes can still be observed in current curricula used by elementary school teachers. Craig held that the elementary school science curriculum should deal with:

1. laws, principles, and concepts of science that are of immediate concern to the daily lives of people,
2. the health, safety, and economic aspects of science, and
3. the attitudinal dimensions of science.

Elements of Craig's philosophy continued to be expanded and developed by science educators, including Craig himself, for many years. Over the years, for example, the National Society for the Study of Education has published several Yearbooks devoted to science education. The first was published in 1932 (the Thirty-first Yearbook) and others followed in 1947 and 1960. Although science education was to become more sophisticated over the years, Craig's initial thinking can be found reflected in each of these Yearbooks. Further, Craig served as senior author of one of America's foremost science textbook series until the early 1970s. Such was his impact and reputation.

The Shame of It All

Regardless of the impact made by Craig and others over the years, problems continued to plague science education. Although elementary school science should have been more attuned to the true cultural role of science, teachers walked into their classrooms across the nation, closed the classroom doors behind them, and proceeded to prostitute the very pedagogy which permitted their employment in the first place—a general education for all children. The science textbook became a reader and where science activity existed, it existed largely for the sake of activity itself without any real concurrent inductive reasoning taking place. The entire premise for science in school was somehow overlooked by poorly trained administrators, inept teachers, and economically oriented textbook publishers (most of which were completely unwilling to try and change the *status quo*). Science educators themselves failed to understand the realities of science and how children learn and therefore, teacher training was only marginally effective as a stimulus for effective teaching.

Thus, for many years, elementary school children were short-changed and exposed only to a descriptive, deductive approach to science—and in some schools (and it continues even today) science was ignored completely. The very nature of science provides one of the most motivating of all tools available to the teacher, and for decades educators were missing the opportunity to "turn kids on" to true intellectual development. We heard about the pedagogy of critical thinking and experiential learning but "fumbled the ball" at the classroom door.

The Spectre of Sputnik

On October 4, 1957, the Russian government pushed a satellite into orbit above the earth. The accomplishment of Sputnik instantaneously created chaos in political, scientific, and education circles. The prestige of the United States, at least in the minds of many leaders, was on the line. The accusation was made, immediately following Sputnik, that the schools in the United States were deficient in the teaching of science and mathematics (although, as J. Murray Lee (1972) points out, when U.S. astronauts walked on the moon, no one rose up to give credit to the schools of the nation).

In any event, the Sputnik episode resulted in a deluge of strategies for improving science education—and other areas of the education system as well. The year following Sputnik saw the passage of the National Defense Education Act (NDEA). The NDEA was intended to help every American develop his skills and competencies to the fullest. According to Piltz (1965) the rationale for this strategy was to help the nation develop its manpower and insure the leadership essential for the preservation of democracy. In accordance with these goals was the objective of improving instruction in such content areas as science, mathematics, geography, English, and reading. Monies were made available via the NDEA for the purchase of equipment, supplies, and instructional materials in these areas. Although many dollars did, in fact, serve to improve educational programs across the nation, much of the money was squandered with reckless abandon by school boards, administrators, and teachers who gave little thought to the educational needs of children and sound instructional programming.

Following NDEA, the Elementary and Secondary Education Act (ESEA) was passed in 1965. The ESEA covered a wide variety of education problems including the education of children from low-income families, improving school library facilities, the implementation of innovative curriculum programs, and supplementary strategies (e.g., instructional materials centers, educational TV programming, learning laboratories), educational research, and the operation of Research and Development Centers as well as Regional Educational Laboratories. In 1968, the Congressional budget for Title III of ESEA alone was $208,000,000. Such was the perceived need for the development and implementation of innovative educational projects.

In addition to NDEA and ESEA, both public and private agencies involved themselves in massive efforts to upgrade the teaching of science at both the elementary and secondary school levels. Of particular interest are the contributions of the National Science Foundation (NSF). NSF has spent hundreds of millions of dollars subsidizing curriculum projects. The "Big Three" experiential elementary science programs developed with NSF funding were Science: A Process Approach (SAPA), Elementary Science Study (ESS), and Science Curriculum Improvement Study (SCIS). Although these programs differ in content, scope, and sequence, they are similar in that each involves development of scientific processes or critical thinking skills in children. Also, there are no textbooks to read; children engage in inductive activities in which thinking and doing give rise to intellectual skills and scientific information. In effect, children model the behavior of the scientist (i.e., the children generate their own information) by using the same intellectual skills that the scientist uses. However, the purpose of these programs is not to turn children into scientists, but to help children become critical thinkers and problem-solvers. In these experiential science programs, the deductive, read-about-science method of textbook instruction gives way to the activity-oriented, inductive method of learning. It is unfortunate to report, however, that less than 25% of U.S. students have ever participated in any of the modern science programs.

The 1980s—The Project Synthesis Report

A recounting of the program development that occurred in the sixties and seventies suggests an encouraging and healthy outlook regarding the status of elementary science education in the United States. From a fairly uniform curriculum in the early sixties, which utilized science "readers" and a deductive approach, the elementary science curriculum moved in the late seventies to a state that reflected a diversity of goals, philosophies, and types of materials. As we move through the decades of the eighties and nineties, it would seem that science education could be an exciting and profitable enterprise for every youngster.

The elementary teacher has a wealth of curricular materials at hand (i.e., the three major NSF projects SAPA, ESS, and SCIS) with their involvement in science process or critical thinking skills, as well as the traditional textbook series still in publication. These materials vary a great deal in intended student outcomes, learning/teaching styles, format, and content, and offer the elementary teacher a variety of science education options.

Despite this wealth of resources, Project Synthesis, the research effort referred to previously in this worktext, revealed a not so encouraging picture of what was going on in the classroom of the eighties. In the words of that document edited by Harms and Yager (1981):

> The typical elementary science experience of most students is at best very limited. Most often science is taught at the end of the day, if there is time, by a teacher who has little interest, experience, or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will probably come from a textbook selected by a committee of teachers at the school or from teacher-prepared worksheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the students but selected because it is "in the book."

There were probably a number of reasons for this state in science education. Project Synthesis indicated that a large number of teachers did not enjoy science and lacked training in science content, skills, and in how to teach science to children. Probably as a result of the insufficient training and the ensuing insecurity, there was a heavy reliance on the textbook and thus a great deal of "reading about" science and not much "doing science."

Other obstacles to effective science education identified by Project Synthesis included a lack of time to prepare for science activities, a lack of equipment, a lack of funding to provide for equipment, and a shortage of storage space. Additionally, few elementary classroom teachers had access to science supervisors for assistance and guidance. Although Project Synthesis seemed to logically define scientific literacy in terms of the student outcomes identified in its four goal clusters, unfortunately (in the authors' opinion) no nation-wide or even wide-spread adoption of Project Synthesis was made.

The 1990s and Beyond

In the late 1980s two major studies were published putting forth ideas pertinent to the direction that elementary science education should take in the 1990s and beyond. One study, The Carnegie Report, has already been presented in this worktext. Many of the goals of The Carnegie Report seem to agree with those of Project Syntheses. For example, The Carnegie Report puts emphasis on students who are healthy both physically and mentally (personal needs), who are responsible citizens capable of analyzing and putting forth solutions for surrounding problems (societal issues), who will have the capacity to think clearly and critically (academic preparation), and who are aware of career options that are unhampered by race, ethnic, or gender restrictions (Career Education/Awareness).

The other report published in the late 1980s was entitled Project 2061. Published by the National Council on Science and Technology, Project 2061 put forth goals which were to be met by the year 2061. Project 2061 was critical of the present science/math curricula calling them "overstuffed and undernourished." Project 2061 asked the schools to teach less in order to teach better. Regarding science/math/technology education, Project 2061 authors propose to narrow the content goals to the knowledge and skills that: are functional for the long-term future; help citizens make intelligent social and political decisions involving science and technology; and are so important to human history and so pervasive in our culture that a general education would be incomplete without them. Specifically, Project 2061 pointed out that the goals of science education (i.e., scientific literacy) include:

1. being familiar with and respecting the unity of the natural world;
2. being aware of the important ways which represent the mutual dependency of mathematics, technology, and society;
3. understanding some of the key scientific concepts and principles;
4. being able to utilize scientific ways of thinking;
5. understanding that science, mathematics, and technology are human enterprises and, therefore, also understanding their strengths and limitations;
6. being able to use science product and processes for individual and social purposes.

Currently, efforts to improve the science literacy of students is being addressed on many fronts. At the federal government level, the National Research Council has been charged with developing science standards for K-12 schooling. It has been working for several years to develop a national consensus on what science education should include, how it should be taught, how students should be evaluated, and how teachers should be prepared. One of the things that sets this effort apart from others regarding setting science literacy standards and directing science education reform is the diversity of input that has been sought in the development of these standards. Leaders in science education, business, government, teaching, research, and the general public have all been involved in developing these standards from the beginning. Feedback on draft editions of the Standards, has been sought from all interested parties. This effort has truly been an attempt to reach a national consensus.

While being different in origin, common threads still connect these Standards with other efforts at deciding what and how science should be taught. The benefits of a scientifically literate society are defined by the NRC as:

1. citizens will be able to use scientific principles and processes in making personal decisions;
2. all citizens will experience the richness and excitement of knowing about and understanding the natural world;
3. economic productivity will increase in a society that is becoming increasingly dependent on scientific and technological skills;
4. informed citizens will be able to participate in debate about scientific issues that affect society.

Notice the similarities between these benefits, the goal clusters of Project Synthesis, and the components of science literacy used by Project 2061 (e.g., goals incorporating personal needs, societal issues, and academic preparation). Regardless of who is doing the writing, there seems to be general agreement about the benefits of a scientifically literate society.

In addition to developing a national consensus regarding scientific literacy, the NRC Standards define criteria for effective teaching, evaluation, and teacher preparation. These Standards describe a science program in which students learn the processes and content of science in a realistic environment, stressing students doing science and reducing dependence on reading about science. Students are assessed using authentic evaluations in which students demonstrate the ability to use science skills in problem solving. Teachers are prepared to teach science by being well grounded in the content, processes, and pedagogy of science education. Perhaps most significantly, the Standards describe a teacher preparation environment in which teachers have the opportunities to both experience science being taught appropriately and actually doing science.

The NRC Standards are not to be taken piecemeal but are intended to provide a basic framework upon which school districts can expand. They also are not a curriculum or individual lessons. It is the responsibility of individual districts and teachers to design the curriculum and lessons to meet the Standards. The Standards provide a foundation to build upon as we try to improve the science literacy of our citizens.

In Summary—Where Have We Been and Where Are We Going?

As science education moves through the 1990s, it might be helpful to recall the history of this discipline in the United States. Spanning the nearly two centuries since the didactic literature ushered elementary science into the United States, various movements and trends in science education have come and gone. The early trend toward classroom use of books that were adapted from the didactic literature was interrupted by the European-born object teaching movement. As object teaching faded and citizens demanded new science curricula, the first modern day thoughts were given to incorporating critical thinking and problem-solving skills into elementary science education. Unfortunately, teachers were unable to implement these new curricula and soon the Nature Study movement, using object teaching and faculty psychology, was widely accepted. Following this movement, Dewey, Craig and others called for the incorporation of intellectual or critical thinking skills into elementary science education. Textbooks which emerged after Craig's dissertation, however, failed to become much more than science readers. The launching of Sputnik spurred the United States government to spend huge amounts of money on education. Some worthwhile experiential science programs were developed which were based to a large extent on helping children learn process or critical thinking skills.

In the early 1980's Project Synthesis put forth four goal clusters, the foci of which vastly broadened the definition of scientific literacy. Project 2061 and the Carnegie Report followed Project Synthesis, both pointing out the direction science education should take in the future. These efforts were followed by the National Research Council's National Science Education Standards, the goals of which are similar to various goals found in Project Synthesis, the Carnegie Report, and Project 2061.

The present state of elementary science education appears to be somewhat uncertain. For the most part, youngsters receive limited experience in science from teachers who have little expertise, interest, or training to teach science. Science equipment (when it is available) receives very little use, if any. Children are most commonly involved in reading about science, memorizing facts from a text, or completing teacher-prepared worksheets. At the same time, more tax dollars are being provided for the implementation of "activity-based" science and for the training of in-service teachers responsible for these implementations. Whether this attempt at "hands-on" science will flourish depends on a variety of variables such as continued funding, teacher training, parental support, local administrative backing, teacher dedication, and many more.

It is important to remember that the needs of our society often determine directions in education. Whether the educational community responds to special interest groups (such as back to basics) or to the current concern for strengthening the science curriculum, it appears accurate to conclude that future trends in elementary science education will probably be, as past trends have been, reactions to historical events and movements, or reactions to and outgrowths of preceding methods of elementary school science instruction.

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APPENDIX B

Writing and Analyzing Instructional Objectives

Appendix B has been prepared to provide practice in analyzing and writing performance objectives. The activities herein should contribute substantially to your understanding of and ability to write performance objectives. In almost all instances, you will be able to find the correct answers and/or example responses for these activities at the end of this appendix. Therefore, you can undertake these activities at your own pace and at a time when you can give them your fullest attention.

Performance Terms

Unless one can measure whether a student has met an objective, it is meaningless. This speaks poorly of the old standby terms such as to *know*, to *appreciate*, and to *understand*. We may wish to get a student to appreciate something, but it is virtually impossible to measure an objective like the following one:

> One of the objectives of this unit is to help children learn how to appreciate the native wildflowers of the Midwest.

Instead, the behaviorally stated objective deals with some *observable* or measurable action. It describes what the student should be able *to do* as a consequence of an educational experience. The objective uses performance terms. Some performance terms follow:

- construct
- compare
- classify
- compute
- write
- select
- describe
- predict
- hypothesize
- experiment
- analyze
- evaluate
- state
- test
- design

The following examples indicate how some of these performance terms (and others) can be used behaviorally. Identify, in writing, the performance terms used in the examples below (make sure you also identify those which are *inferred* as well as *overt*):

1. Given a multiple choice test item, the student will select the response that correctly defines the term *mineral*.
   (What is/are the performance term(s) in No. 1)? ______________________________

   ____

2. The student will be able to write a hypothesis that can be tested experimentally.
   Performance term(s)? ______________________________

   ____

3. The student will write a design of an experiment to test the hypothesis.
   Performance term(s)? ______________________________

   ____

4. Upon completing the unit, the student will be able to correctly classify twenty different line drawings of insects into groups according to insect orders.
   Performance term(s)? ______________________________

   ____

5. The student will show his appreciation for the need to conserve water by inspecting his home and repairing all leaky faucets found there.
   Performance term(s)? ______________________________

   ____

6. While comparing four specimens of reptiles, the student will be able to orally state one way in which they are all similar and one way in which each differs from the others.
   Performance term(s)? ______________________________

   ____

(Note: Correct responses can be found at the end of this appendix.)

Are They Behaviorally Stated?

Below you will find listed six separate objectives. In the blank in front of the objective, write "yes" if the objective is written in behavioral terms and "no" if it is not.

______ 1. The student will be able to classify twelve geometric shapes into three separate groups by placing them in three piles, each of which contains closely related kinds.

______ 2. The student will orally state an accurate definition of work.

______ 3. The student will perceive the relationship between work and energy.

______ 4. The student will develop an appreciation of natural resources and form an accurate concept about how he can participate in environmental education.

______ 5. The student will prepare a written list that includes three examples of biotic community factors and four examples of abiotic factors.

______ 6. The student will demonstrate a positive attitude toward the need for recycling glass by purchasing pop only in reusable containers.

Of the six objectives stated, four are written behaviorally and two are not. You should have responded "no" to numbers three and four. The term "perceive" is not a performance term nor is "appreciate." There is no way a person can observe directly someone else's understanding and appreciation. It is true that these things can be measured, but not directly.

How might you revise numbers three and four so that the desired outcomes can be observed and, therefore, evaluated? Rewrite these below:

Revision:

Revision:

There is no *one* way to measure either desired outcome. However, regardless of how the evaluation is done, it must be consistent with the knowledge, skill, or attitude desired. If you want to see examples of the revisions, please refer to the end of this appendix.

Applying What You Have Learned

In the following four problem situations you are asked to write certain instructional objectives in behavioral terms. In each instance your objectives are to clearly reflect the appropriate parameters for an objective. Similarly, the objective must correctly reflect the problem. It must be consistent with the operation(s) demanded of the students for whom you are writing the objective. Please be accurate in all dimensions.

PROBLEM I: Your second graders have been involved off and on through autumn with a unit on seasons. They started the first day of fall and ended the first day of winter. They kept a weekly diary of environmental changes as they observed them. One activity was to measure the length of a post's shadow every Monday at exactly 10:30 a.m. (Standard Time).

On completion of the unit you want your students to know (among other things) that their shadows will be longer at a given time in November than they were on September 22. Also, you want them to know that, as fall progresses toward winter, North America is receiving less light energy from the sun and, as a result, it gets colder from September 22 throughout the fall season.

Below, write instructional objectives that will measure these learnings.

PROBLEM II: Your intermediate students are just beginning a unit on energy exchanges in biology. The book they use makes a big point of the fact that almost all food energy in the biological world comes directly or indirectly from organisms that contain chlorophyll and carry on photosynthesis. Also, photosynthesis is the process whereby green plants manufacture carbohydrates (sugars and starches) by chemically combining carbon dioxide (CO_2) and water (H_2O) in the presence of chlorophyll and light energy (usually sunlight).

You want your students "to know" three things: (1) what photosynthesis is; (2) the relationship between carbon dioxide, water and carbohydrates in the green plant; (3) the relationship between photosynthesis and food energy in the biological world. Write three instructional objectives in behavioral terms that measure the student's knowledge in each of these dimensions. Do this below:

PROBLEM III: You are involved in a unit on soil conservation with your fourth grade students. You have discussed Midwestern soil conservation problems. You have shown several good films that illustrate soil conservation problems and methods of attacking these problems. Many of these problems and conservation strategies are similar to those observable in the Midwest. Also, you ask the local soil conservationist to come in and talk to the students about these things. He also agrees to lead a field trip to area farms where numerous problems and conservation techniques can be observed.

Write an instructional objective that would allow you to assess whether your students can apply what they have learned in the classroom to what they see in the field. They must exhibit knowledge about both problems and conservation strategies. Do this below:

PROBLEM IV: You are teaching upper grade students about food chains and food webs in the environment. You illustrate the food chain concept by using an example from the forest community. The example begins with the food producing green plant (an oak) that produces acorns. Some of these acorns are eaten by chipmunks that live on the forest floor. The chipmunk is a first order consumer in this instance. The chipmunk, in turn, is eaten by a coyote who acts as a second order consumer.

Following this simple food chain example you proceed to tell the students that food webs are more complex. The acorn, for example, is not always eaten by the chipmunk. It can be eaten by a squirrel. It could be eaten by a number of different insects. Any of these animals could be preyed upon by others. The same is true for the chipmunk. It could be preyed upon by a fox, a redtailed hawk, or a great-horned owl. It might also have a couple of worm parasites living in its intestine. These are all factors that should be considered in a food web involving numerous organisms.

You want to find out whether your students understand the *difference* between a food chain and a food web. Similarly, you also want *evidence* to indicate that they can reconstruct a simple food chain and a fairly simple food web. Write *one* instructional objective that will measure *both* of these desires. Do this below:

Correct Responses for Appendix B.

Performance Terms:

1. select, (define)*; 2. write, (hypothesize)*; 3. write (design)*; 4. classify; 5. inspect, repair; 6. compare, state. (*performance terms that are inferred in the individual statements (e.g., in No. 2, the student is asked to write a hypothesis, so the inferred task is hypothesizing). The student is not asked to experiment in No. 2, so experimentation would not be a performance term in No. 2.)

Are They Behaviorally Stated? (Example Responses)

3. The student will prepare a written statement, not to exceed 50 words, which describes the relationship between work and energy.

4. The student will present a 10 minute oral report which partially explains the importance of soil, water, forest, and wildlife resources. Subsequently, he will state one way in which he can successfully participate in the conservation of at least three of these resources.

Applying What You Have Learned: (Example Responses)

1. Asked whether his shadow is longer at 2:00 p.m. on September 22 or on November 22, the student will respond with the correct answer.

   Asked if his home town or school gets more light energy from the sun in October or November, the student will respond with the correct answer. Subsequently, when asked if it gets colder or warmer from September to December, he will respond correctly.

2. Following the lesson on energy exchanges in the biosphere, the student will be able to . . . (a) . . . elect the correct response in a multiple choice test item which explains that photosynthesis is the process whereby green plants manufacture food. (b) . . . orally state the names of the two compounds which are chemically combined in the presence of chlorophyll and light energy when carbohydrates are being produced by a green plant. (c) . . . write a sentence of no more than 20 words explaining the relationship between photosynthesis and food energy in the biosphere.

3. Following the unit on soil conservation the student will, given a sheet of paper on which five soil conservation problems are listed and five control measures listed, be able to orally state the locations where three of each of these were observed during the field trip.

4. Following the instruction on food chains and food webs the student will be able to construct a simple diagram of a food chain (minimum of three steps) and a diagram of a food web (showing relationships of at least three organisms in a food web), label each organism as to whether it's a producer, first-order consumer, etc., and state in writing which diagram is the food chain and which is the food web.

APPENDIX C

Supplementary Reading Assignment

This assignment is designed to broaden your background in a facet of elementary school science education which is of particular concern or interest to YOU. The number of readings required in this assignment plus continued reading (done on your own) will help keep you abreast of current thinking in the field. The assignment is meant to be an opportunity to give you an indepth view of the topic you choose.

INSTRUCTIONS:

1. You will choose a topic in elementary science education, either from the suggested list found below or one of your own interest (*which requires the agreement of your instructor*). Samples of topics are: 1) discovery learning in science; 2) process instruction; 3) question-asking strategies; 4) the unit approach to science education; 5) science career awareness; 6) instruction in science-related social issues; 7) science for the gifted child; 8) developing scientific attitudes; 9) motivation in science; 10) using community resources in science; 11) integrating science with other subjects; 12) use of field trips (or outdoor education) to teach science; 13) environmental education; 14) concept development in science; 15) the textbook and its place in science education; 16) teaching science experientially; 17) using science in special education; 18) teaching science to the young child; 19) use of microcomputers in science teaching; 20) evaluation of science learning.

2. You will then read at least *SIX* (6) journal articles *on your chosen topic*. Please select a topic on which you can find sufficient, current journal coverage (1980 to present). SUGGESTED JOURNALS ARE:

   Science and Children
   The Science Teacher
   The American Biology Teacher
   Scope
   Instructor

   Also use the *Reader's Guide* and the *Education Index*. Pertinent articles often appear in such journals as *Illinois Education;* the NEA Journal; *Today's Education; Learning;* the *Kappan* and others. Please be sure that the articles you choose directly relate to your topic.

3. After reading these articles you will prepare a 1000 word paper (maximum), which is to be a brief summary of the topic on which you have become knowledgeable. This *is not* to be a discussion of the six separate articles. Use the ideas gleaned from your articles in your discussion of the topic. You should also evaluate the information read in the articles as part of the paper's coverage.

4. The end-product (paper) is to be a *typewritten, concise, coherent, smooth-flowing* synopsis (summary) of the topic you selected. The paper will include:

    a. a title page designating your topic and identifying your authorship.

    b. the paper itself (watch your word limits—1000!) NOTE: one doublespaced typewritten page constitutes 250 words.

    c. citations within the paper (incorporated into your synopsis) of some of the bibliographical references you used. A good way is to use the name of the author of the article if you paraphrase or quote from your references. *PLEASE DO NOT USE FOOTNOTES.* A sample citation form is: Smith (1979) stated that science is important for general education purposes.

    d. a final paragraph containing *YOUR HONEST EVALUATION* of the ideas you have presented in this paper. Platitudes and glittering generalities are not appreciated. You might want to evaluate the usefulness of methods for valuable science learning, for example.

    e. a bibliography (on a separate sheet of paper) of the articles you used (READ) to gather information for your topic. Your bibliography *must* include *AT LEAST TWO DIFFERENT* journals within the six you have listed. The bibliography is to be done in a standard, correct style. One such example is presented below:

Saunders, G. W., Wise, K. C., Golden, T. S. (1995). Visual learning. The Science Teacher, 62(2), 42-45.

5. *DUE DATE:* As announced by your instructor.

6. *GRADING:* Your grade will be based on the degree to which your paper has met the guidelines of this assignment. The following criteria will be used:

    a. organization and discussion of the topic

    b. cited use of references in the paper

    c. bibliography (relevancy of articles, diversity of journals, correct form)

    d. summary—your evaluation of the topic covered (quality and depth of perception)

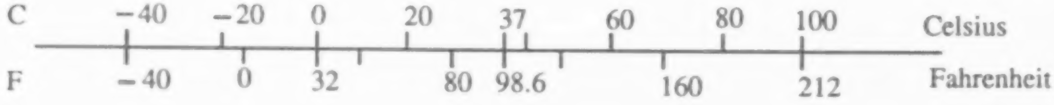
    e. grammar, spelling, neatness.

APPENDIX D

Metric Measure

The universal system of measurement in science is the metric system. This appendix is provided to give you some assistance in seeing the relationships between the metric and English systems. It is highly recommended that you have your students make all measurements in the metric system rather than getting them involved in converting English system measurements into metric ones.

Temperature:



To obtain a Celsius temperature, subtract 32 from the Fahrenheit temperature. Take 5/9 of that figure. Example:

212 F
$\underline{-\ 32}$
180 x 5/9 = 100 C.

To eliminate fractions, a second way is to subtract 32 from the Fahrenheit temperature and divide that figure by 1.8. The formula for this process is $C = F - 32/1.8$.

To obtain a Fahrenheit temperature multiply the Celsius temperature by 9/5. Add 32 to this figure. This yields Fahrenheit temperature. Example:

37 C x 9/5 = 66.6
$+\ \underline{32.0}$
98.6 F

To eliminate fractions, another method is to multiply the Celsius temperature by 1.8 and then add 32 to that derived figure. The formula for this method is $F = 1.8C + 32$.

Weight (Mass):

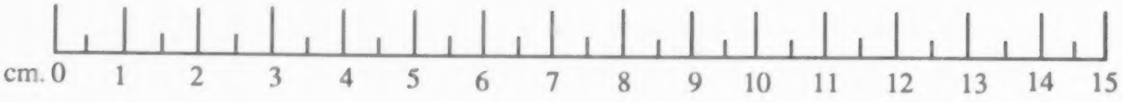
1 ounce = 28 grams (g)
1 pound = 0.45 kilograms (kg)
1 ton (2000 lb. = 0.9 tonnes (t)

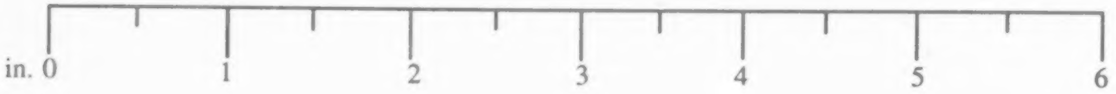
* * * * * * *

1 gram (g) = 0.035 ounces
1 kilogram (kg) = 2.2 pounds
1 tonne (1000 kg) = 1.1 tons

Linear Measure:

Approximate conversions both ways . . .





1 inch = 2.54 centimeters (cm)
1 foot = 30 centimeters (cm)
1 yard = 0.9 meters (m)
1 mile = 1.6 kilometers (km)

* * * * * * *

1 millimeter (mm) = 0.04 inches
1 centimeter (cm) = .4 inches
1 meter (m) = 3.3 feet
1 meter (m) = 1.1 yards
1 kilometer (km) = 0.6 miles

Volume:

1 milliliter (m) = 0.03 fluid ounces
1 liter (1) = 2.1 pints
1 liter (1) = 1.06 quarts
1 cubic meter (m^3) = 1.3 cubic yards

* * * * * * *

1 teaspoon = 5.0 milliliters (ml)
1 tablespoon = 15.0 milliliters (ml)
1 ounce = 30.0 milliliters (ml)
1 pint = 0.47 liters (1)
1 cubic yard = 0.76 cubic meters (m^3)

APPENDIX E

TEXTBOOK APPRAISAL

Your Name ______________________________ Date __________

Title of Textbook ______________________ Grade Level Chosen _____

Author(s) ____

Publisher _______________________ Publication Date __________

Content Included in the Textbook

Please examine the textbook carefully. Below you will find listed the major content areas recommended by the National Science Education Standards for inclusion at various grade levels. Please check those which receive substantive coverage in the textbook which you are analyzing.

Levels K-4

___ Properties of objects and materials
___ Position and motion of objects
___ Light, heat, electricity, and magnetism
___ Characteristics of organisms
___ Life cycles of organisms
___ Organisms and environments
___ Properties of earth materials
___ Objects in the sky

Levels 5-8

___ Properties and changes of properties in matter
___ Motions and forces
___ Transformations of energy
___ Structure and function in living systems
___ Reproduction and heredity
___ Regulation and behavior
___ Populations and ecosystems
___ Diversity and adaptations of organisms
___ Structure of the earth system
___ Earth's history
___ Earth in the solar system

PART I—SCIENTIFIC LITERACY

Personal Needs Goals

1. Is there evidence in the student text to indicate that students gain a concept of what science is? This could be accomplished through a direct definition, discussion, or through repeated reference to science. Although a child might gain the concept inductively, by experiencing science in a realistic manner, you must provide an adequate explanation if you use this perspective in your answer.

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

2. Does the textbook cover mental and/or physical health as a basic part of science? In particular does it assist children in forming good health habits and valuing a healthy body/lifestyle?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

3. Does the textbook enable children to be successful consumers in a scientific and technological society?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence

Societal Issues Goals

4. Does the textbook present information dealing with science-related social issues? Examples of these issues might include endangered plants and animals, soil erosion, acid rain, human population growth, etc.

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

5. Does the textbook develop an appreciation of both the potential and the limitations of science and technology with respect to solving societal issues?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

6. Does the textbook help students develop the abilities to analyze science-related social issues, and to make sound decisions and deal responsibly with those issues

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Academic Preparation Goals

7. Does the textbook cover a variety of important science concepts?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

8. Do students receive training in specific scientific processes in this series, e.g., hypothesizing, comparing, classifying, predicting, and experimenting?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence

9. Does the textbook provide for the development of scientific attitudes (e.g., respect for empiricism, curiosity, demand for verification, suspended judgment)?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Science Career Awareness Goals

10. Does the textbook develop an awareness of scientists and technicians as real people?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

11. Does the textbook present information on a wide variety of careers related to science and technology?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

12. Does the textbook present illustrations of or anecdotes about individuals of both genders, numerous ethnic groups, and various handicaps in science-related careers?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

PART II—INSTRUCTIONAL APPROACH

Questions

Questions are asked of students in all science texts. They are found interspersed within chapters, at a special section at the end of the chapter, or in both places. Please study the manner in which the authors have asked those questions.

13. Do the authors ask questions which measure the acquisition of concepts rather than simple recall?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

14. Do the authors ask questions which measure the ability of the child to apply concepts in new and unique situations?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Activities

Most texts claim that they are activity (experientially) oriented and support hands-on science education. Their activities, often called experiments or investigations, are found interspersed within chapters or units, at a special section at the end of the chapter, or in both places. Carefully examine the manner in which the authors have presented these activities.

15. Are the activities structured in such a way as to have the students inductively form a concept? That is, do the students experience hands-on science before they read about or discuss a concept

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

16. Are the activities developed so that there is an opportunity for open-ended, independent investigation, rather than simply following a prescribed sequence of events which lead to a predetermined answer?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Evaluation

17. Are the children evaluated in a manner which is consistent with stated objectives and/or textual material?

Not At All		Somewhat		Very Well
0	1	2	3	4

Evidence:

Concept Development

Most textbook publishers make a point of noting that a particular text develops important concepts. Choose any one specific concept from anywhere in the text, state the concept below, and continue with this part of the appraisal as directed below. (An example concept: Energy is exchanged in the environment through food chains beginning with the food-producing green plant.)

State the chosen concept in this space:

Page:

18. What printed information and/or illustrations are found in the text which would help the child develop this particular concept?

19. What science experiences (laboratory or otherwise) do students get with regard to this particular concept? In other words, what do students DO to help them learn this concept?

20. What suggestions are there in the Teacher's Guide for the development of this concept?

21. Do your answers to questions 18, 19, and 20 above provide enough information and experiences to permit the thorough development of this concept? Defend your answer! Think it through carefully!

The Teacher's Guide

22. Please inspect the Teacher's Guide for the text that you are analyzing. Respond to the following:

Does the Teacher's Guide ...

a.... clearly present instructional objectives for each unit/chapter? Yes No

b.... provide the teacher with adequate supplementary information on the science content being presented to the students in each unit/chapter? Yes No

c.... provide the teacher with lists of resources he/she may go to for further information on the science content being presented in each unit/chapter? Yes No

d.... communicate teaching methodologies which would maximize teacher effectiveness in teaching the units/chapters? Yes No

e.... provide the teacher with descriptions of supplementary materials (e.g., films, filmstrips, videos, trade books) which could be used profitably with students? Yes No

f... provide suggestions to the teacher for integrating science content with other content areas in the curriculum (e.g., reading, social studies, composition, mathematics)? Yes No

g.... reflect an organization which would facilitate the teaching of the unit/chapter (i.e., make the teacher's task easier and more efficient)? Yes No

SUMMARY

You will now be asked to make a recommendation regarding the use of this science textbook series. Assume that, for one reason or another, you had to use this textbook series as the basic science program. Please think this through carefully, as you do the following:

23. List what you believe to be the major strengths of this textbook series as related to scientific literacy.

24. List what you believe to be the major weaknesses of this textbook series in relation to scientific literacy.

25. Prepare a detailed explanation of how you would use this series, modify it, or supplement it, in order to provide the best possible science program for our youngsters. In other words, how could we use this series to provide for scientific literacy on the part of our students? Please be very specific in your response.

Appendix F

Safety in the Classroom

Safety in the classroom is an important consideration at all times but is particularly critical during activity based learning involving student moving around the room and working with equipment, chemicals, living organisms or other materials. This concern for safety is one of the reasons frequently given by teachers for not teaching science in a hands-on manner. While safety must be a concern, it need not be a reason for avoiding hands-on science.

The key safety word in a legal sense is "reasonable caution." In other words, were the precautions taken those that would be taken by a "reasonably prudent person." They do not have to be extreme, but do need to demonstrate good sense and forethought. The guidelines given at the end of this section are not meant to be exhaustive, but should provide a measure of guidance as you plan hands-on science activities.

Safety precautions should be a part of all lesson plans. Be sure to write down all safety precautions taken and directions given to students prior to doing an activity. This is your best defense if an accident does occur and someone questions the precautions you have taken. Also, all accidents should be recorded. The records should include name date, time, and location of the accident, nature of the accident, injuries and treatment provided. Be sure to determine what policies or procedures your school has developed for such cases.

Most states do not require it, but obtaining Basic First Aid training from a recognized organization such as the American Red Cross is an excellent idea. Information about First Aid courses can be obtained from your local hospital, Fire Department or local chapter of the American Red Cross.

A more detailed discussion of safety in the classroom is presented in "Safety for Elementary Teachers" by Downs and Gerlovich. The software package "The Total Science Safety System" Gerlovich, Gerard and Hartman is also very informative. The checklists provided for chemical storage, reporting accidents and classroom arrangement are particularly useful.

Safety in the Classroom: Points of Consideration

1. Is the room arranged so that students and teachers can move freely without bumping into other students or equipment? Aisles five (5) feet wide are recommended to accommodate handicapped students. Are there extra tables for distribution of materials and storing student projects?
2. Are materials for immediate use located in such a manner that can be accessed without congestion?
3. Are materials stored in closed cabinets? Science equipment and supplies, especially chemicals should not be stored on open surfaces where children may have unsupervised access.
4. Plastic containers, tubing and graduated cylinders are preferable to plastic except when necessary such as for heating.

5. Are there sufficient outlets so extension cords are not required?
6. Is a first aid kit available in the room? Is antiseptic soap available? Where is the nearest fire extinguisher?
7. Have you checked student health records for allergies? Make special note of children with diabetes or other conditions that may be affected by activity.
8. When doing demonstrations, are children seated a safe distance away?
9. Is water available in the room?
10. When using heat or open flame have you advised students about keeping long hair tied back?
11. Have local, state and federal laws pertaining to the collection and use of animals been observed?
12. Are the hazards presented by certain plants recognized?
13. Have students been instructed beforehand on specific safety measures they must observe? These precautions may include general safety measures to be observed at all times plus specific safety concerns of specific activities.
14. Are out of school experiments properly supervised by adults?

Safety Analysis: The Application

You will be assigned an activity for which you are to conduct a safety analysis. This analysis should include targeting specific potential hazards, identifying precautions you would take prior to and during the activity and safety equipment that should be available during the activity. A model Safety Sheet is provided on the following page.

Additional Resources

Science Safety Guidelines
National Science Teachers Association
1840 Wilson Blvd.
Arlington, VA 22201-3000

American Red Cross, (1993). Community First Aid and Safety. Mosby Lifeline, St. Louis, MO.

Downs, G. E. & Gerlovich, J. A., (1983). Safety for Elementary Teachers. Iowa State University Press: Ames, IA.

Flinn Catalog Reference Manual, Flinn Scientific Inc., P.O. Box 219 Batavia, IL 60510.

The Total Science Safety System for Elementary Teachers, by Gerlovich, J.A., Gerard, T, & Hartman, K.,

Available from:
JaKel, Inc.
585 Southfork Dr.
Waukee, IA 50263
515-225-6317

Observing the Candle: Safety Sheet

Name:______________________________

Lesson Title: Observing the Candle

Text: Hungerford et al Grade Level: 5 and up

Give a Brief Outline of the Activities:

Students are to make a list of critical observations about a candle. Students may light the candle. Observations will be analyzed for sense used, inferences and quantitative or qualitative in nature.

Safety Concerns	Precautions Taken

Available Safety Equipment: ______________________________

____

____

____

____

Safety Sheet

Name:____

Lesson Title:____

Text:__________________________________ Grade Level: _______

Give a Brief Outline of the Activities:

Safety Concerns	Precautions Taken

Available Safety Equipment: ______________________________________

____

____

____